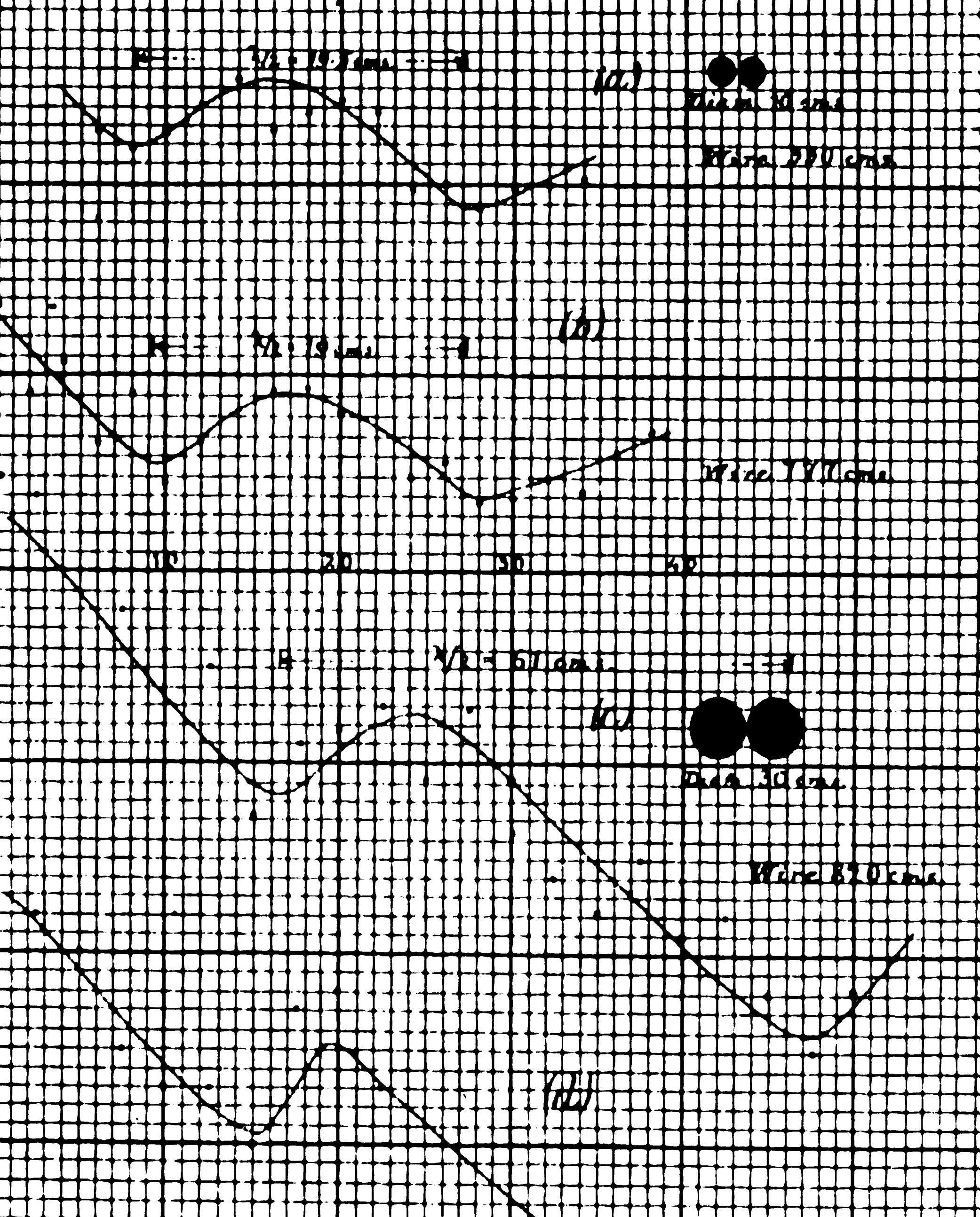

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[FOURTH SERIES.]

ART. I.—*The Morphogenesis of Platystrophia. A Study of the Evolution of a Paleozoic Brachiopod;* by EDGAR ROSCOE CUMINGS.

FEW fossils present features of as great interest and importance, both to geologists and zoologists, as the Brachiopoda, and among them, few are as familiar as the genus *Platystrophia*, the "Orthis lynx" of collectors. Wherever Ordovician rocks are exposed the geologist may expect to meet with this ubiquitous and characteristic genus. The regularity with which it turns up in collections from new localities is little short of amazing, and perhaps, if familiarity breeds contempt, accounts for the indefinite and hazy notions current as to its real history and the interrelations of its component elements.

The writer has made an attempt in a preliminary paper to obtain some measure of the variability of *Platystrophia* and out of that study has grown a deeper interest in this form and a deeper insight into its history. The present study is based upon the method of investigation of post-embryonic growth stages, which we owe to Alpheus Hyatt and his able exponents of the present day, Beecher, Jackson, Smith and others. I have endeavored to make full use of specimens representing all stages of growth and all the elements of the range and distribution of *Platystrophia*. The *mere study of growth stages* has not been deemed adequate unless supplemented by series of adults; and it is hoped that in this way is escaped the error of depending on one class of evidence. That this method thus supplemented has proved potent in discovering unsuspected relationships among the members of a genus which has attracted widespread attention for nearly a century, will be evident to those who follow the present discussion to its close.

The order of presentation is, first, the development of *Platystrophia* under the heads *Nepionic*, *Neanic*, *Ephebic* and

*Gerontic** stages: second, a critical discussion of the several adult types variously known as species and varieties of *Platystrophia:* and third, a general résumé and discussion of the history of the genus and the laws of its evolution.

The material used in this investigation belongs in part to the author's collection, which contains several thousand specimens coming from every division of the Cincinnati Group of the Ohio Valley. In addition the Yale Museum contains, besides many specimens from Cincinnati and vicinity, specimens from the Trenton of New York, Kentucky, Tennessee, and Minnesota; from the Galena of Minnesota; from the Clinton of New York and Kentucky; from the Silurian (Niagara) of Anticosti and the Island of Gotland; and from the Ordovician of Wesenberg, Russia. Mr. P. E. Raymond very kindly gave me a series of specimens from the lower Trenton of Crown Point, New York; and Mr. C. J. Sarle of Rochester, N. Y., loaned me a series from the Clinton of that vicinity. Dr. J. M. Clarke loaned for study specimens from the Rysedorph conglomerate (basal Trenton) in the vicinity of Albany, N. Y. Mr. Chas. Schuchert of the U. S. National Museum loaned specimens from his private collection and the collection of the museum, representing the following localities and horizons: St. Petersburg, Russia (Ordovician); Gotland, Sweden (Silurian); Gasport and Lockport, N. Y., Eaton and Dayton, Ohio, and Osgood, Indiana (all Silurian). Prof. R. T. Jackson of Harvard University with great kindness allowed me to study their unrivalled collection of *Platystrophia*, containing many thousand specimens from Cincinnati, Ohio (Ordovician). Dr. G. F. Matthew sent me for study his types of *Orthis lenticularis* from St. John, N. B. To Prof. H. S. Williams of Yale University the writer is indebted for opportunity to examine material from the Ordovician of Arkansas, and for suggestions which his wide acquaintance with kindred subjects renders of especial value. To Prof. C. E. Beecher, who has afforded me every facility and encouragement during the prosecution of this work, the author is under deep and lasting obligations.

Development of Platystrophia.†

I. *Nepionic stages.*—The youngest individuals seen (fig. 1), have a breadth of 1^{mm} and a length of $0{\cdot}66^{mm}$. They represent an early nepionic stage. They are markedly transverse,

* For a classification of the stages of growth and decline as applied to the Brachiopoda, the reader is referred to Beecher's paper on the Development of the Brachiopoda, this Journal, vol. xliv, 1892, pp. 150–154, pl. i. The substitution of the forms *Neanic*, *Ephebic* and *Gerontic* for *Nealogic*, *Ephebolic* and *Geratologic* is in accordance with present usage. See Hyatt, Phylogeny of an Acquired Characteristic, Proc. Am. Phil. Soc., xxxii, pp. 390–397. See also Proc. Bos. Soc. Nat. Hist., vol. xxvi, pp. 93–108.

† Schlotheim's original description of *Terebratulites* (= *Platystrophia*) *biforatus* is so difficult of access that it is here quoted in full:

having an index* of 1·5, and the greatest breadth about one-third of the way from the beaks to the front margin. The posterior margin (cardinal line) is straight, and the anterior semielliptical. The greatest height is at the beaks, which project slightly beyond the area, but are not incurved. The area is considerably less than the width of the shell at the hinge; and the large foramen is about equally shared by the two valves. At the apex of the ventral foramen is a small callosity. No deltidium was observed.

Ventral valve.—In the initial specimens, this valve, for about half the distance from the beak to the front margin, is without longitudinal markings of any sort; but shows a number of very faint concentric lines. The anterior half of the

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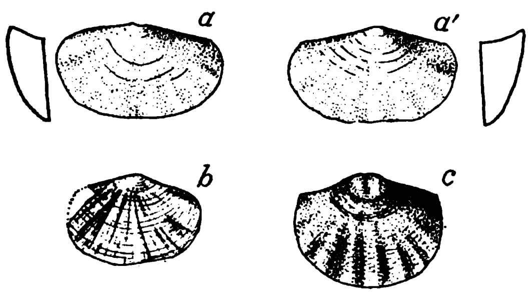

FIG. 1. *a*, Nepionic stage of *Platystrophia*, from specimen obtained at Vevay, Indiana. *a*, dorsal valve, showing median sinus and four plications on either side, profile to left; *a′*, ventral valve showing median fold and four plications on either side, profile to right; ×22. *b*, *c*, *Orthis lenticularis* var. *lyncioides* Matthew; figures of the types: *b*, ventral valve of a transverse individual showing bifurcation of several plications toward the anterior margin; *c*, ventral valve of a narrower individual with very strong plications. The umbonal region is exfoliated. *a*, Author's collection.

valve is thrown into nine low rounded plications. One of these occupies the median line, originates nearer the apex, and is slightly more prominent than the others, thus forming a median fold. Toward the front margin the plications are very faintly crenulated by obscure concentric lines.

"22. Terebratulites biforatus

"Ein freyes ganz vollständig, mit versteinerter Schaale erhaltenes Exemplar, aus dem südlichen Frankreich. Vielleicht gleichfalls aus Kreide-lagern der Champagne. (1 ex.)

"Mit ganz gleichen, breiten, länglichrunden Halften, deren Schnäbel gleichförmig gewölbt und auf beyden Seiten durchbohrt sind. Die Oberschaale mit einer breiten concaven Rückenfursche, die untere Hälfte mit convex hervorstehenden Rücken. Beyde Hälften gleichförmig der länge nach gestreift, mit ziemlich tiefen zwischenfurschen. Ausserordentlich selten."

Die Petrefactenkunde auf ihrem jetzigen Standpunkte, etc., Gotha, 1820, p. 265.

No figure is given.

* Breadth divided by length = shell index.

Dorsal valve.—As in the ventral valve the posterior half is smooth, with faint concentric lines. The anterior half is occupied by eight plications. The depression (sulcus) between the two inner ones is deeper and broader than between the others, giving the effect of a median sinus corresponding to the large median plication or fold of the ventral valve. The convexity of the dorsal valve is nearly as great as that of the ventral.

Comparison with nepionic stages of other Orthidæ.—At the stage represented by the youngest specimens of *Platystrophia* (1^{mm} broad), *Dalmanella (testudinaria, elegantula)* and *Rhipidomella hybrida** have twelve plications on each valve, which arise very close to the apex. The valves are convex, though the dorsal usually has a sinus (sometimes conspicuous) toward the front. The areas are high and well developed, not, however, extending to the cardinal extremities. The ventral area is noticeably higher than the dorsal. The delthyria in both valves are large and open.

Bilobites at this stage has nine plications on the ventral valve, one of which lies at the bottom of a shallow median sinus. These originate, as in *Platystrophia*, about half-way from the beaks to the front margin. The areas are high and the delthyria large and open. The relative convexity of the two valves is almost exactly the same as in *Platystrophia*.†

Hebertella at $1{\cdot}4^{mm}$, the youngest stage yet seen, has eighteen plications which originate very near the beak. The valves are both convex, the ventral being considerably higher. The areas are high and about perpendicular to the plane of separation of the valves.

All the young *Orthidæ* seen, with the exception of *Bilobites*, have noticeably transverse shells:‡ but in all other respects, except the index, the young *Bilobites* most closely resembles the nepionic *Platystrophia*.

Comparison with adult stages of other Orthidæ.—There are no adult *Orthidæ* in the Ordovician with which it is possible to compare the nepionic shell of *Platystrophia*.§ Wysogorski has suggested the derivation of the genus from the *Orthis calligramma* group.‖ His views are based entirely upon adult characters of both groups. He says (loc. cit.) "In both groups the

* For the development of *Dalmanella elegantula* and *Rhipidomella hybrida* see Beecher and Clarke, Mem. N.Y. State Museum, i, 1889, pp. 13–18.

† For the development of *Bilobites*, see Beecher, this Jour. xlii, July, 1891, pp. 51–56.

‡ The index of *Dalmanella* is 1·33 or more, and of *Hebertella* 1·43. That of *Bilobites* is only 1·13 (Beecher's figures).

§ *Orthis lapworthi* Davidson, from the Llandeilo—Middle Caradoc of England, comes the nearest, and is probably an almost lineal descendant of *Orthis lenticularis* of the Upper Cambrian.

‖ Zur Entwicklungsgeschichte der Brachiopodenfamilie der Orthiden im ostbaltischen Silur. Sonder-Abdruck aus der Zeitschrift d. Deut. Geol. Ges. Jahrg., 1900, Heft 2, p. 14.

muscular impressions are the same; many individuals of the *Orthis calligramma* group manifest a tendency to form a sinus, which in *Platystrophia* is so strongly developed that with the corresponding fold of the dorsal valve it constitutes a chief characteristic of this subgenus." It is only necessary to state that the presence of a sinus in the ventral valve of adult Brachiopoda is so nearly universal as to be of little use in tracing phylogenies. As a matter of fact the *nepionic* shell of *Platystrophia* has the sinus in the *dorsal* valve and the fold on the *ventral*. Though this feature also characterizes many specimens of *O. calligramma*, nevertheless the fact that a dorsal sinus is a nepionic feature of such widely separated forms as *Dalmanella*, *Rhynchonella*, *Rhynchotreta*, *Rhynchospira*, *Cœlospira*, *Atrypa*, etc., renders this character of little significance in indicating a common origin of *O. calligramma* and *Platystrophia*.

The ancestors of *Platystrophia* are scarcely to be sought in the Ordovician, since the genus is already represented in the lower beds of this system.* In the Upper Cambrian, however, we meet with a form that possesses in the adult practically all of the nepionic characters of *Platystrophia*. This form is *Orthis lenticularis* Wahlenberg sp., a widely distributed and highly variable species, found in the Lingula-flags of Wales, the Alum schists of Scandinavia, and the equivalent formations of Canada.† Through the kindness of Dr. G. F. Matthew I have obtained for examination the types of his var. *lyncioides* of this species, from the Upper Cambrian of St. John, N. B. These are shown in fig. 1, *b* and *c*.‡ The contour of fig. 1*b* is precisely

* *Platsytrophia* has several times been stated to occur in the Chazy of this country, (see Hall and Clarke, Pal. N. Y., viii, pt. i, p. 202.—Winchell and Schuchert, Geol. Minnesota, iii, pp. 456, 457.—Schuchert, Bull. U. S. G. S., No. 87, p. 309; Proc. U. S. National Museum, vol. xxii, 1900, p. 151 (Birdseye).—Ruedemann, Bull. N. Y. State Museum, No. 49, Dec., 1901, p. 92). I am unable to find any original reference in the literature to its occurrence in rocks of this age. Messrs. Ami, Whiteaves, and W. Billings of Ottawa, Canada, inform me that the museum of the Canadian Survey contains no Chazy specimens; and that they are not aware that the species has ever been found in that series. Mr. Billings suggests that it may have been found in rocks formerly held as Chazy, but now known to be of later age. Mr. McBride of Montreal writes that there are no Chazy specimens in the museums at Montreal and that he does not know of the occurrence of *Platystrophia* in the Chazy. Mr. Seely, who is familiar with the Chazy, writes to the same effect. It is very probable therefore that the form is not known to occur below the Trenton in this county.

† For synonomy and descriptions of this species see Davidson, Silurian Brachiopoda, 1869, pp. 230–232:—Matthew, Trans. Roy. Soc., Canada, ix, 1891, Sec. iv, pp. 46–49. Wysogorski (Entwicklungsgeschichte, p. 8, footnote 1) places *O. lenticularis* in the genus *Orthis* emend. Wysog., which includes the impunctate *Orthidæ*.

‡ These two specimens are figured by Matthew (op. cit., pl. xii, fig. 10). His fig. 10*b* represents the same individual as our fig. 1*b*. It should be noted that all the plications reach the front margin and several of them bifurcate, giving, as shown in our figure, several additional plications at that point.

like that of the nepionic *Platystrophia* (fig. 1*a'*)—a ventral valve in both cases. *O. lyncioides* also has a strong median plication and about four weaker ones on either side. The posterior half of the valve is devoid of longitudinal markings, but possesses concentric lines. The beak is well elevated, though the area is not exposed in any of Dr. Matthew's specimens. As shown in Davidson's figures of *O. lenticularis* the area is high and the foramen large and triangular.* Our fig. 1*c* indicates that the ventral muscular impression is about the same as in other primitive *Orthidæ* (*Platystrophia*, *Plectorthis*, etc.).

The name which Dr. Matthew has given this pretty little variety of *Orthis lenticularis* indicates, as he also expressly states, that he considered it as a possible ancestor of *Platystrophia.* My own conclusion to the same effect was reached independently through a comparison of the nepionic *Platy-*

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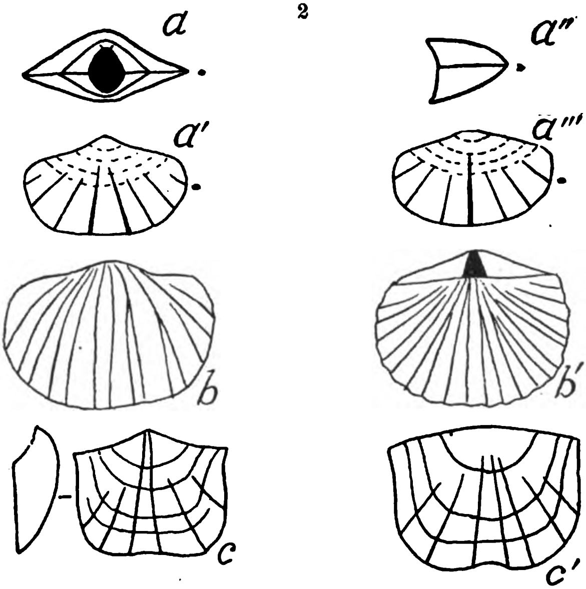

FIG 2. *a, a', a'', a'''*, posterior, ventral, profile and dorsal outline views of the nepionic *Platystrophia*; actual size shown by small figures to the right. *b, b'*, ventral and dorsal views of *Orthis Hicksii*, after Davidson. *c, c'*, ventral and dorsal views of *Orthis salemensis*, after Walcott.

strophia with Davidson's figures of *O. lenticularis.* Aside from the strong resemblances pointed out above, the wide distribution, great abundance, and high variability of this species make it an ideal ancestral type. It may very well have produced, on the one hand, the pauciplicate group, *Platystrophia*,

* Silurian Brachiopoda, 1869, pl. xxiii, fig. 26a.

Orthis s. s. *Dinorthis*, *Plectorthis*, etc.; and on the other the multiplicate group *Hebertella*, *Dalmanella*, etc.

In the Middle Cambrian, *Orthis Hicksii* Salter,* fig. 2*b*, has many of the nepionic characters of *Platystrophia* and may be the ancestor of *Orthis lenticularis*.

The Lower Cambrian furnishes very few Brachiopods of an Orthid aspect: but *O. salemensis* Walcott,† an outline figure of which is given here (fig. 2*c*), again strongly suggests the nepionic shell of *Platystrophia*. In the present state of our knowledge of Cambrian forms it is perhaps unsafe to speculate far in regard to phylogenies of any sort; nevertheless I am inclined to believe that some such form as *O. salemensis* constitutes the final link between the *Orthidæ* and the primitive Brachiopoda of the type of *Kutorgina cingulata*.

II. *Neanic stages.*—The specific characters of *Platystrophia* do not begin to appear until the shell has reached a breadth of 3^{mm} or more. At about this size, the demarcation of the true fold and sinus, which began at a little over 2^{mm}, has produced a noticeable sinuosity of the margin (as viewed from the front). At the bottom of the sinus is a single plication—the same that formed the ventral fold of the nepionic shell. On either side of the sinus are four or five plications (including the ones immediately bounding it). The dorsal valve has the two median plications slightly elevated, forming a fold; and the sulcus between them represents the continuation of the median dorsal sinus of the nepionic shell. (These stages are shown in fig. 3, IV, V.)

A little later (fig. 3, VI), usually at about the breadth of 4^{mm}, two additional plications make their appearance in the sinus at its front margin, one on either side of the primary plication. In the dorsal valve at this stage the two plications of the fold are each seen to bifurcate, giving four in all. The typical number of plications of the fold and sinus of *P. lynx* are now present, though the lateral slopes still possess only five or six. Further increase in the number of plications of the slopes takes place by addition at the cardinal angles, and never (with the rarest exceptions) by bifurcation of those already formed, or by implantation between them. In a shell of 6 or 7^{mm} breadth it is usually possible to determine the variety, therefore the neanic period may be said to cease at that size.

In well preserved material it is possible to study the neanic stages at the beaks of adult specimens; and these stages and those immediately following (early ephebic) are of the utmost importance in tracing lines of descent within the genus. Three

*Davidson, Silurian Brachiopoda, 1869, p. 230.
† Tenth Ann. Rep., U. S. G. S., 1891, p. 612, pl. 72, fig. 6.

of the species which are here recognized as belonging to *Platystrophia* are marked by important differences at this stage.

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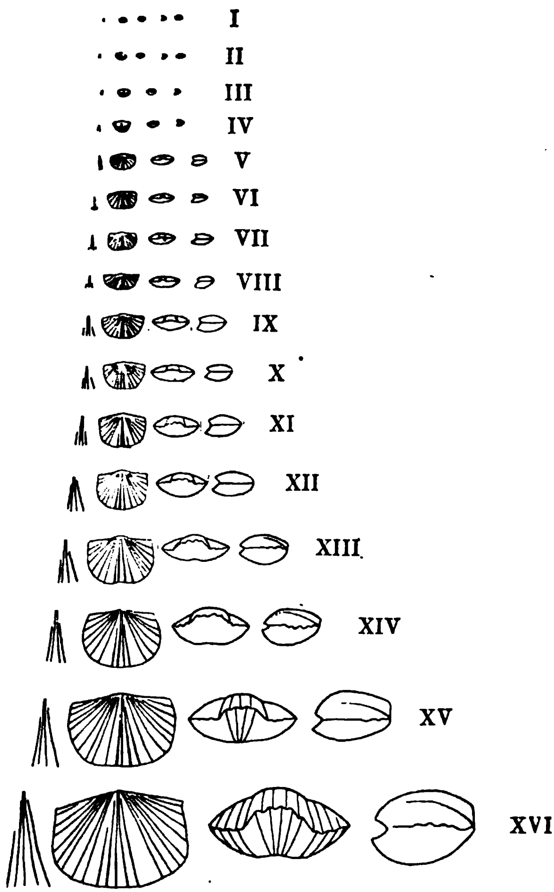

FIG. 3. Series of specimens of *Platystrophia lynx* from Vevay, Indiana, showing change in contour, profile, and convexity of shell with advancing growth. I, specimen 1^{mm} broad, nepionic stage, natural size, same specimen as fig. 1*a*. V, beginning of neanic stage, in which the dorsal fold and ventral sinus become defined. The early ephebic stages are represented by numbers XI to XVI, the latter being a nearly adult individual, possessing four plications in the sinus. The method of origin of the plications of the sinus is shown to the left of each row. All natural size. Author's collection.*

* In all the outline figures in this paper *the lines correspond to the depressions between plications*, and the *interspaces to the plications* themselves.

The above described mode of origin of the plications of the fold and sinus applies to all American Ordovician forms, with the exception of some from the basal Trenton. It does not apply to Upper Silurian forms nor does it seem to apply to Ordovician forms of the Russian Province. Though I have not been able to obtain specimens of Upper Silurian forms of *Platystrophia* in the nepionic stage, nevertheless several adult individuals from the Island of Gotland are so perfectly preserved that even the nepionic stages can be studied at the beaks. In the Gotland specimens, precisely as in the Ordovician specimens just described, there is at first a median ventral fold and a median dorsal sinus. A little later the ventral fold becomes depressed between the two adjacent plications of the valve, and this median plication of the ventral sinus thus formed, immediately bifurcates, making the two main plications of the sinus of all Upper Silurian forms. On the dorsal valve the two plications bounding the median sinus become elevated, and a third is implanted between them, making the three main plications of the dorsal fold of all Upper Silurian forms. All the Russian Ordovician forms studied also belong to this type, as will be shown in a later paragraph.

An examination of thousands of specimens of American Ordovician forms, and scores of specimens of Silurian forms reveals no real exception to the above described modes of origin of the plications of the fold and sinus.* Yet some confusion seems to exist on this very point.

In the Geology of Minnesota, vol. iii, p. 456, occurs the following statement in regard to the development of *Platystrophia:* "The writers [Winchell and Schuchert] regret their inability to secure very young specimens of this species for the purpose of determining the ancestors or line of development. In several immature individuals it has been observed that in the early nealogic [neanic] stage the beaks are strongly elevated, probably erect, and each has a very large open delthyrium, surface smooth at first, but gradually developing eight plications and a mesial sinus in each valve. The sinus in the dorsal valve is bounded by two elevations which become plications, and between them is soon developed a single costa which immediately bifurcates. The four plications increase in strength and become strongly elevated as they proceed to the anterior margin, producing the conspicuous fold of the valve."

With the first part of this statement my observations are in full accord. In regard to the origin of the plications,

* Some specimens from the basal Trenton, to be described later, are of the Upper Silurian type.

however, it is necessary to state that the method they describe has only been observed in an occasional specimen of Upper Silurian (biplicate)* type and therefore does not apply to any of our Ordovician *Platystrophias* above the basal Trenton. In no case have I seen a mesial sinus in both valves, at any stage in development. The true method of origin of the plications in American Ordovician forms was pointed out by Hall in 1847.†

It remains to note some apparent exceptions to the above rule in regard to American Ordovician forms. Very rarely in the Cincinnati group an individual of *Platystrophia costata*‡ occurs with three full plications on the fold and two in the

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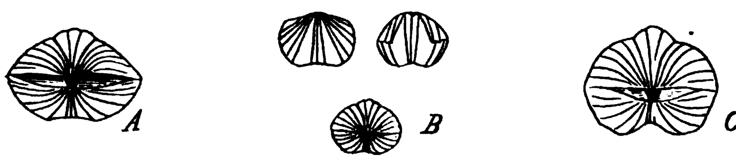

FIG. 4. *A* and *C*, specimens of a pauciplicate *lynx* from Cincinnati, Ohio, in which the third plication of the sinus is suppressed, causing the shell to simulate *P. dentata*, shown at *B*. In *C* the lateral plication of the sinus is clearly seen to be implanted; and less clearly though just as certainly in *A*. In *P. dentata* as shown in *B* (a specimen from Russia) the primary plication of the sinus bifurcates. *A* and *C* from the Dyer collection, Museum of Comparative Zoology, Harvard University. *B* from collection of the U. S. National Museum.

sinus. In the Dyer collection at Harvard, which contains several thousand specimens of this variety, I noticed perhaps half a dozen such individuals. In the majority of these the type is manifestly triplicate, since the second plication of the sinus is implanted at the side of the primary and does not originate by the bifurcation of the primary. The third plication is simply suppressed. I saw but two individuals (fig. 4, *A* and *C*) in which the primary plication seemed to bifurcate, and even here a close inspection of the beak shows that the second plication is really implanted.

Another apparent exception is that of the type in which there is but one plication in the sinus. A careful examination

* It is convenient to speak of forms of *Platystrophia* having *two main plications* in the sinus, originating as just described the Silurian type, as *biplicate*. Those having *three* characteristic plications, as in nearly all American Ordovician forms, are similarly called *triplicate;* and those having but *one* plication in the sinus, *uniplicate*.

† Pal. N. Y., vol. i, 1847, pp. 133-134.

‡ The American form known as *dentata* Meek, and *crassa* James, has been shown to be the same as *costata* Pander. See this Journal, July, 1902, p. 14, footnote.

of numerous individuals has, however, demonstrated the fact that even this type is fundamentally triplicate.* The details of this point will appear later. Suffice it to say that here again the secondary plications have been suppressed. They may often be seen more or less distinctly in the rostral region, but fade out toward the front. With the one exception, therefore, noted above, all the Ordovician forms of this country belong fundamentally to the triplicate type.

Comparison with adult stages of other Orthidæ.—The early neanic shell with one plication in the sinus and five on each lateral slope is strikingly suggestive of the var. *costata* of Russia and the lower part of the Cincinnati group of this country. As just pointed out, however, the latter is evidently derived from a triplicate type such as we find abundantly represented in the Trenton. Practically any group of *Platystrophia* may produce an occasional uniplicate individual. Fig. 15*f* shows it in the normal *costata;* fig. 15*a* in the var. *laticosta.* In the *lynx* group it is extremely rare. Only one example has come to my notice. Theoretically there should be a uniplicate *Platystrophia* in the lowest Ordovician. If this stage was passed before any definite differentiation of the fold and sinus took place, then some of the small *Orthidæ* of the Calciferous and Chazy come very near the requirements. Otherwise I know of no form corresponding to the theoretical uniplicate type.†

In some respects the adult *Plectorthis plicatella* resembles the neanic *Platystrophia.* If the sinus and fold be disregarded (and in some Trenton forms these are surprisingly inconspicuous), the neanic *Platystrophia* is almost a *Plectorthis.* There is little doubt that when the nepionic shell of *Plectorthis* is discovered it will be found to be quite indistinguishable from the nepionic shell of *Platystrophia*, since the two groups present at the beaks almost identical characters. *Plectorthis* appears in American faunas in the Black River formation,‡ and *Platystrophia*, as we have seen, in the basal Trenton. *Plectorthis* may therefore represent an offshoot from the *Platystrophia* group near its initiation or, as sug-

* For the uniplicate European forms I cannot speak. From what I can infer from a careful study of their range and variation, they also probably sprang from a triplicate or biplicate type. This subject will be discussed more in detail later.

† I have gone over the large collections in the Yale Museum, from Crown Point and other well known localities of Chazy and Calciferous fossils. No doubt the connecting form between *Orthis lenticularis* and *Platystrophia* will come to light when much more complete investigations of these old Ordovician rocks are made.

‡ Mr. P. E. Raymond figures and describes specimens of *Plectorthis plicatella* from the Black River limestone of Crown Point, N. Y. (Bull. Am. Paleontology, No. 14, 1902, p. 88, pl. 19, figs. 5, 6.)

gested above, it may have been separately derived from the *Orthis lenticularis* stock.

III. *Ephebic stages.*—The ephebic stages begin with the assumption of characters of lowest taxonomic rank (varietal) (see fig 3; XI–XVI). During these stages there is no marked change in the number of plications, though these may be added, or in the case of the fold and sinus, subtracted, until the final assumption of gerontic characters. The convexity of the valves increases progressively, and the incurvature of the beaks becomes more and more pronounced. The pedicle often

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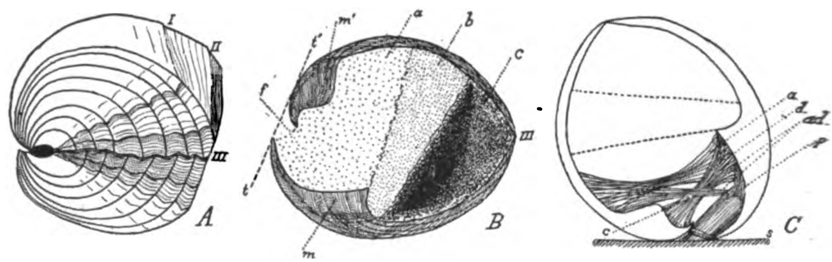

FIG. 5. Very large senile individual of *Platystrophia lynx* from the upper Lorraine of Vevay, Indiana; × ½. *A*, profile; *B* and *C*, sections in the median plane. Normal adult growth was attained at varix No. *I*. The successive additions of shell substance are shown in *B*, and the probable musculature in *C*. The pedicle has entirely abandoned its original foramen and encroaches on the umbonal region of the ventral valve; the apex of the dorsal valve lies in the ventral delthyrium. The shell was partially infilled with very fine silt, probably while still standing in its natural position, with the shell resting on the plane *tt'*(*s*). *f*, pedicle passage; *mm'*, muscular platforms of dorsal and ventral valves respectively; *a*, *b*, oxidized and unoxidized portions of infiltrated material; *c*, cavity lined with small crystals of calcite; *C*, *a*., adductor muscle; *d*., diductor; *ad*., adjustors; *p*., pedicle; *c*, position of hinge axis. Author's collection.

encroaches on the apex of the ventral valve, even sometimes in early ephebic stages. All, or any of these changes may affect any one of the forms under which *Platystrophia* is known. Other modifications affecting the ephebic stages can more conveniently be discussed under the heads of these various forms.

IV. *Gerontic stages.*—Old age manifests itself in *Platystrophia* by increasing gibbosity, thickening of the shell, pronounced growth varices, and obsolescence of plications, and at times by marked changes in the contour of the shell (shell index). Though senile individuals are met with in all the types of *Platystrophia*, *lynx* and *acutilirata* afford the best examples of it, and in many specimens from the upper range of these species senescence begins early in the ontogeny.

Of these gerontic modifications, the thickening of the shell and obsolescence of plications are the most important. The former character is well shown in fig. 14, and the latter in fig. 12. The thickening of the valves is responsible for the increasing incurvature of the beaks. In extreme cases (fig. 5 *A*) this causes the pedicle to encroach on the ventral beak to such an extent as to completely abandon its normal foramen, which is invaded by the dorsal beak.

Fig. 5 represents the largest specimen of *P. lynx* seen. *C* shows it in its natural position during life with an indication of the musculature. This individual is decidedly senile, complete ephebic growth having terminated at the varix No. *I*, though the amount of thickening of the shell is not as great as in many smaller individuals (cf. fig. 5*B* and fig. 14*B*).

Platystrophia acutilirata presents even more extreme gerontic modifications than *P. lynx*. The greatest gibbosity seen in any group occurs here, and the amount of change in the shell index is truly remarkable. It will be more convenient, however, to discuss the details of these changes due to senescence under the heads of the several species and varities of *Platystrophia*.

*Platystrophia lynx.**

The species commonly known in this country as *Platystrophia lynx* is beyond any question the most abundant and widespread Ordovician member of the genus, and also bears the greatest resemblance to the species commonly known as *Platystrophia biforata* (Schlotheim). Hall † does not attempt to distinguish between them. Davidson ‡ says in regard to the British specimens, "We certainly have the type *biforata* and the variety *lynx*, but these two seem so intimately connected that I have combined them under Schlotheim's single designation [*biforata*]." According to von Buch,§ *lynx* has four plications in the sinus and on the fold‖ and nine on each side. Schlotheim's *biforatus*, he says, is "very nearly related" to *lynx*. The former has five plications in the sinus and nine on each side and is broader than *lynx*. According to de Verneuil¶ "The *S.* [*Spirifer*] *biforatus* proper seems to be rare; we have, as had Eichwald, a single specimen very poorly preserved. His came from Reval and ours from the neighbor-

* Eichwald, Skizze von Podolien, 1830, p. 202.

† Pal. N. Y., i, 1847, p. 132.

‡ Silurian Brachiopoda, 1871, p. 271.

§ Essai d'une classification et d'une description des Delthyris, etc., Mem. Soc. Géol. France, iv, 1840, pp. 190, 191.

‖ He certainly was mistaken in either the number on the fold or in the sinus. There is always one more on the fold.

¶ Géol. de la Russie, 1845, pp. 136, 137.

hood of St. Petersburg. The beaks, as in most *Spirifers* from the latter locality, are small, appressed and render it difficult to view the double area" (p. 136). Of *lynx* he says, "This variety differs from *S.* [*Spirifer*] *biforatus* only in the less number of plications in the sinus . . . . . M. Eichwald says he found it in the drift near Grodno, with two plications in the sinus, three on the fold and eleven on the sides" (p. 137).*

So far as concerns the characters mentioned above as distinctive of *lynx* and *biforata*, it must be admitted that none of them are of any value. *Platystrophia lynx* has all the way from one to seven plications in the sinus and may have from six to twelve on either side; and varies in shell index between the limits of 1·0 and 1·8.†

It is altogether likely that the *biforatus* type does not occur in American upper Ordovician faunas; and the same may be true of Eichwald's species, *lynx*. The latter certainly and Schlotheim's species in all probability, came from Russia. In regard to *biforatus*, von Buch. (loc. cit.) says, it "very likely came from the north and not from France." With our present knowledge of the species we may be sure it did not come from France, at least, if it is an Ordovician type at all. It may very likely have been obtained in the same manner as *P. lynx* from glacial pebbles.‡

I have before me specimens of the *lynx*, *biforata*, and *dentata* types from the Ordovician of Russia. All of these show a peculiarity that I have never seen in an American so-called *biforatus* or *lynx*, from beds of equivalent age, namely, the presence at the beaks of three plications on the fold and two in the sinus. This peculiarity, as has been pointed out, invariably characterizes Silurian forms both American and foreign.§

Figures 6, 4*b* and 21*e*, are of these Russian types; and show the number and arrangement of the plications of the fold and sinus. Fig. 21*e*, of the ventral valve of a specimen of *P.*

* The shell index of *biforatus* given by deVerneuil is 1·5 : that of *lynx* 1·3.

† Schuchert says (Bull. U. S. G. S. No. 87, 1897, p. 308), "Individuals of a stratum . . . . are fairly constant in form, size, and plications, and it is this limited constancy that has served in many of the following species [*biforata*, *lynx*, *laticosta*, *acutilirata*, *crassa*]." Even this "limited constancy" can scarcely be found in many localities, for I have seen several of the varieties *together in a single slab of limestone*.

‡ It should be remembered that Schlotheim *distinctly states* that his "one example" of *Terebratulites biforatus* came from Southern France. Either he was mistaken or this type is a Mesozoic *Spiriferina!*

§ Mr. A. F. Foerste (Bull. Dennison University, i, 1885, p. 80) was the first to call attention to the fact that Silurian forms have an odd number of plications on the fold and an even number in the sinus, while the reverse is true of Ordovician forms. While this is not strictly true, it is true that the Silurian forms have *at the beak*, without exception, three on the fold and two in the sinus.

biforata from Wesenberg,* Russia, shows five plications in the sinus. To the left is shown the arrangement of these plications. At the apex there is a single plication which immediately bifurcates. Then a plication is implanted between the two thus formed, and immediately bifurcates giving four plications. Between the two last formed is now implanted

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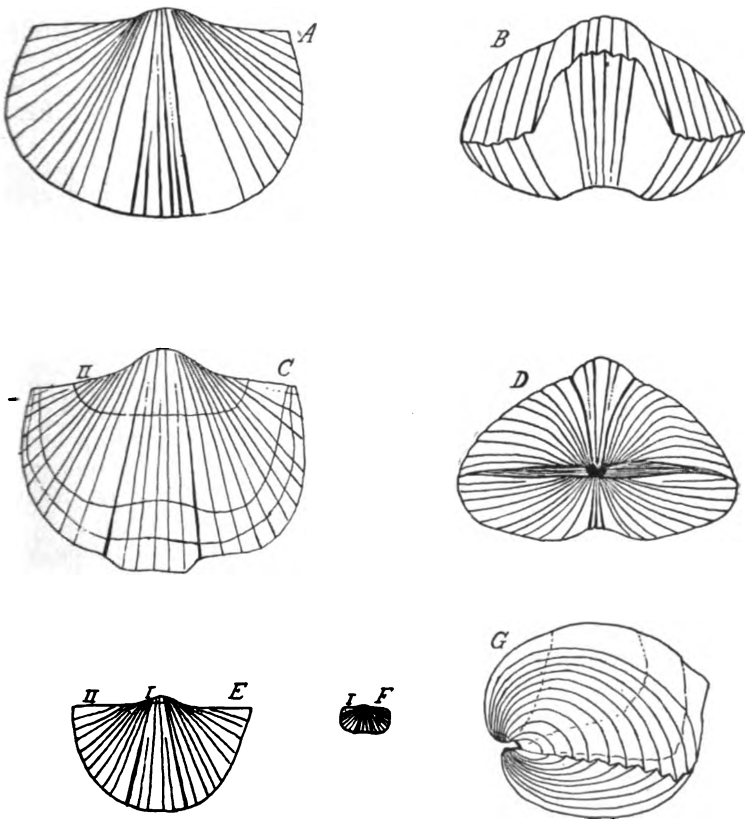

Fig. 6. ***Platystrophia biforata*** **(*P. lynx* of authors) from Pulkowa, Russia. *A–D* ventral, anterior, dorsal, and posterior views; *E*, stage *II.* (see *C*) drawn separately; *F*, stage *I.* (see *E*) drawn separately; *G*, profile, showing strong incurvature and great size of dorsal valve.† Collection U. S. National Museum.**

another plication, making five. Fig. 21*e′*, of the dorsal valve of the same specimen, shows six plications on the fold, which as seen in the diagram to the left originate as follows: first, two

*** This specimen and the next to be described were labeled by F. Roemer.**
† All figures natural size unless otherwise stated.

appear at the apex; between these, one is implanted and almost immediately bifurcates; and between these two, another is implanted and bifurcates, making six in all.

Another specimen of *P. biforata* from Wesenberg, Russia, has four plications in the sinus and five on the fold, but they originate in precisely the same way. The last plication added on the fold does not, however, bifurcate; and the unpaired median plication of the sinus is wanting.

In a specimen from Pulkowa, Russia (near St. Petersburg), labeled *P. lynx*, there are (fig. 6) six plications on the fold and five in the sinus. These originate as follows: In the sinus one plication appears at the apex and immediately bifurcates. Each of the two thus formed bifurcate, and the one to the left bifurcates again, giving five in all. On the fold two plications appear at the apex and one more is almost immediately implanted between them. Each of these three now bifurcate, giving, at the front margin, six plications. The specimen therefore belongs to the same type (biplicate) as the Wesenberg specimens. It is impossible to make sure from the literature of the Russian *Platystrophia* whether this peculiarity characterizes all Russian forms. According to Wysogorski,* who is very familiar with the *Orthidæ* of the Baltic-Province, "the form from the Upper Silurian of Gotland is characterized by smaller size [than the Russian form] while in other respects it agrees with *Platystrophia biforata* Schloth." I have examined some thirty specimens of the Gotland form and these invariably have three plications on the fold and two in the sinus. If Wysogorski has taken this peculiarity into consideration, his statement is strong evidence, in support of that afforded by the Russian specimens which I have examined, as to the biplicate character of all these Russian types. None of the earlier authors shed any light on this point. De Verneuil gives several excellent figures of the *lynx*, *dentata* and *chama* (=*costata*) types and mentions a *lynx* from Grodno with two plications in the sinus. In his figures of *lynx* four plications are shown on the fold but their mode of origin cannot be made out, though they are all shown to originate closer to the apex than is common in our American *lynx*, and even closer than in the *lynx* from Cincinnati, Ohio, figured on the same plate. Whenever four plications are present on the fold of biplicate types, they certainly come in closer to the apex than the four plications of triplicate types. Nevertheless, such evidence as afforded by the figures in question cannot be considered as of any particular value.

Davidson's figures and descriptions of British Ordovician

* Entwicklungsgeschichte, p. 15.

specimens leave us almost equally in the dark on this point.* Fig. 12 of *biforata* certainly seems to be of the triplicate type, the same as our Trenton and Cincinnati *lynx*. The var. *fissicostata*, on the other hand, is more probably of the biplicate type; as are certainly all the Wenlock forms figured. On the whole, it seems quite likely that the majority of Russian, if not of all European Ordovician forms of *Platystrophia*, belong to the biplicate type. *In this country, however, the biplicate type is absolutely restricted to the Silurian and basal Trenton.*†

This difference in the mode of origin of the plications of the fold and sinus is of fundamental importance. It has been shown that in nepionic stages of all forms, whether American or European, Ordovician or Silurian, there is a median plication or fold on the ventral valve and a median sulcus or sinus on the dorsal valve. This nepionic ventral fold becomes the primary plication of the ventral sinus of later stages. In triplicate and uniplicate types this primary plication remains simple; but in biplicate types it bifurcates near its point of origin, i. e., in an early neanic stage. Such a difference characterizing so early a stage of the shell certainly *points to the origin of the peculiarity very early in the history of the genus;* and it is consequently very significant that the only place where the two types, biplicate and triplicate, are associated together in American faunas, is in the basal Trenton of the Hudson-Champlain area.‡ The question whether there is a similar association of the two forms in the early Russian deposits cannot with the material at present available be definitely settled.

Platystrophia seems to have made its appearance in Russian seas at fully as early an epoch as in American. Wysogorski states that it occurs first in the Echinosphærites limestone.§ Schmidt lists *P. lynx* from Erras, Reval and Odensholm in beds from the "vaginatum" limestone to the Borkholm.‖ Wl.

* Silurian Brachiopoda, 1871, pp. 268-273, pl. xxxviii, figs. 11-25.

† These basal Trenton forms from the Hudson-Champlain area will be described under the *biforata* type, to which they belong. The fact that they are of the biplicate type, taken in connection with the further fact, brought out by Ruedemann, of the general European aspect of the Lower Ordovician faunas of the Hudson Valley area, is certainly in striking accord with the evidence already adduced as to the predominance of the biplicate type of *Platystrophia* in European faunas. See also Ulrich and Schuchert, Bull. N. Y. Mus. No. 52, 1902, pp. 633-663.

‡ An apparent exception to this statement has been discussed under the subject of neanic stages.

§ Entwicklungsgeschichte, pp. 14, 15.

‖ Untersuchung über die Sil. Form. von Ehstland, etc. Archiv. für die Naturkunde Liv.-, Ehst.- und Kurlands, 1ter ser., 2ter Band, 1858, p. 213.

Lamansky cites *Platystrophia biforata* from the "planilimbata" limestone.* As to the correlation of these beds with American strata there is unfortunately no unanimity of opinion. Schmidt is disposed to consider the Echinosphærites limestone as the equivalent of the Quebec Group of this country; and the vaginatum as equivalent to our Black River formation.† In Kayser's Lehrbuch der Geologie (1891) the Echinosphærites limestone is placed higher than the Trenton and the vaginatum as equivalent to the Trenton.‡ The planilimbata limestone would then be about equivalent to our Black River. Substantially the same correlation is given by Neumayr§ and by de Lapparent.‖ It seems probable, therefore, that the first appearance of *Platystrophia* in Europe was at least as early as in this country, and perhaps earlier: and since it was during this early Ordovician epoch that the two main types of the genus were being differentiated, we may expect to find both in the European as well as in the American deposits of that age.

From the above discussion it appears that there existed after the early Ordovician two distinct types of *Platystrophia*, one of which (the triplicate) characterized the American Ordovician, and the other (the biplicate) the European Ordovician and the Silurian of both America and Europe. Both of these types or species include several varieties. It is also evident that the terms *lynx* and *biforata* have been very loosely applied to both of these types. Since the term *lynx* has become so strongly associated with the American group of shells (triplicate type), I propose to limit the term to such American Ordovician shells. It is impossible to say whether the type of *P. biforata* is biplicate or triplicate. The presumptions are strongly in favor of its being biplicate. I, therefore, propose to restrict the term to biplicate forms such as the Wesenberg specimen above described. It will then include Ordovician forms of Europe, and Clinton forms of both Europe and America. For the biplicate shells with few plications such as are found in Gotland, the Wenlock of England, and Anticosti, the term *dentata* will be used. Further details of the species *biforata* and *dentata* will be given later.

Derivation of Platystrophia lynx.—According to the above interpretation and restriction of *P. lynx*, this form probably

* Neue Beiträge zur vergleichung des Ost-Baltischen und Scandinavischen Unter-Silurs. Centralblatt für Min. Geol. und Pal., Neues Jahrb., 1901, No. 20, pp. 611–618.

† Quar. Jour. Geol. Soc., xxxviii, 1882, pp. 520, 521; Archiv. Liv.-, Ehst.- und Kurlands, 1ter ser., 2ter Bd., 1858, p. 48.

‡ Op. cit., p. 64.

§ Erdgeschichte, 1895, vol. ii, p. 98.

‖ Traité de Géologie, 1900, p. 824.

stands nearer the radical stock than any other. The case in which the nepionic ventral fold remains simple and unmodified throughout the life of the individual certainly must be considered as more primitive than the case in which the nepionic fold bifurcates. It is known that in nepionic and early neanic stages of brachiopods, plications are added by implanta-

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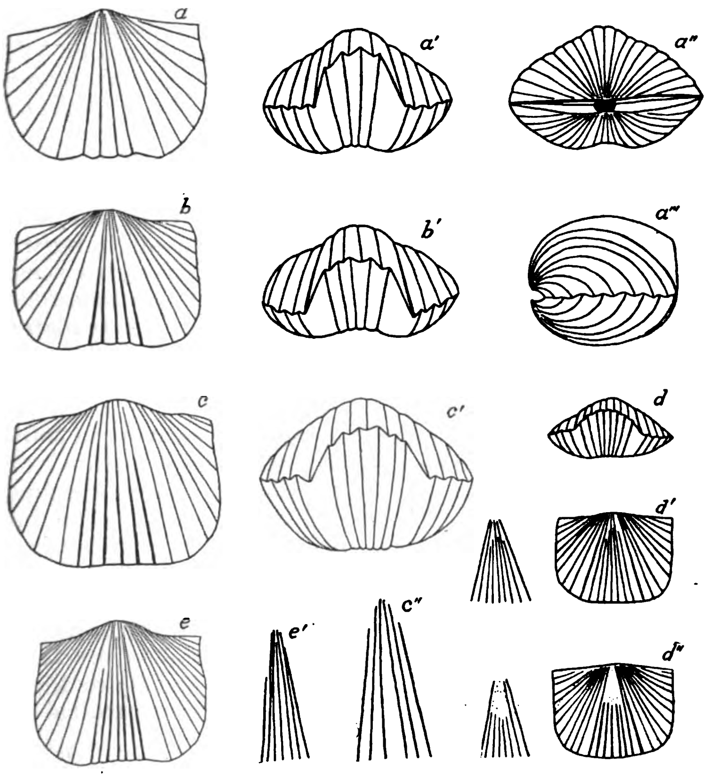

FIG. 7. *Platystrophia lynx* from Vevay, Indiana, showing variation in number of plications of fold and sinus. *a a'''*, ventral, anterior, posterior and profile views of a normal individual with the normal number, three in sinus and four on fold; *bb'*, ventral and anterior views of individual with four plications in sinus, the fourth originating by bifurcation of the left lateral; *cc'*, ventral and anterior views of individual with five plications in sinus, the two additional plications are implanted, *c''*, diagram showing method of origin of plications; *ee'*, individual with six plications in sinus; *dd''* (with diagrams to left of *d'* and *d''*), individual with seven plications in sinus; *d'*, dorsal; *d''*, ventral views. Author's collection.

tion except in highly accelerated types. We must believe, therefore, that a tendency of the primary plication of the

sinus to bifurcate manifested itself as an adult character in the ancestors of *Platystrophia biforata*, and that, subsequently, acceleration crowded back the point of bifurcation into early neanic stages.

The most primitive *Platystrophia* should, as stated in another place, be uniplicate, and it was from such a uniplicate stock that both *P. lynx* and *P. biforata* were derived. The fact that in *lynx* there is no modification of the fold and sinus until an *advanced* neanic stage, while in *biforata* such modification takes place, as explained, at an *early* neanic stage, indicates that *lynx* is nearest to this primitive *Platystrophia*. *P. lynx certainly stands as the radical of all our Ordovician forms above the basal Trenton.*

Variation of Platystrophia lynx.—This subject has already been investigated quantitatively and the results published.* As that investigation applied to specimens from the Middle Cincinnati group only, there is considerable to add in regard to Trenton forms and especially in regard to some highly accelerated forms from immediately beneath the Clinton limestone at Richmond and other localities in Indiana. The Vevay material, quantitatively studied, included the varieties *laticosta* and *costata*, which were shown to pass by insensible gradations into the normal *lynx* type.†

The *lynx* group of the Trenton varies extensively in contour and number of plications, as has often been pointed out.‡ Fig. 8 shows the contour of a series of sixteen specimens, taken at random, from Trenton Falls' material. The index here varies from 1·2 to 1·82, the average being 1·42 and the largest class 1·4. The angle between the hinge line and lateral line of the shell (cardinal angle) varies from 80° to 110°; the number of plications on the ventral valve from 17 to 24, and the number in the sinus from 2 to 6. No. 32, fig. 8, is a composite of Nos. 1-16 inclusive and shows the normal Trenton Falls' type of shell. This shell has a cardinal angle of 90°, with very slight auriculation.§

* Cumings and Mauck, A Quantitative Study of Variation in the Fossil Brachiopod *Platystrophia lynx*. This Journal, July, 1902, pp. 9-16.

† Mr. F. W. Sardeson has expressed the opinion that all the so-called varieties of *Platystrophia* in the Cincinnati group are distinct.

A careful study and measurement of over 2,000 individuals and inspection of some 8,000 others, has failed to establish a specific distinctness. See Sardeson, Am. Geol., vol. xix, 1897, p. 109. Compare also Williams, Geol. Biology, pp. 315, 321.

‡ See especially Hall, Pal. N. Y., vol. i, 1847, pp. 133, 134. Winchell and Schuchert Geol. Minn., iii. 1893, pp. 456, 457.

§ When there is any auriculation of the cardinal extremity the measurement is made between the hinge line and a line tangent to the cardinal extremity and the lateral margin, as shown in fig. 8 *bis*.

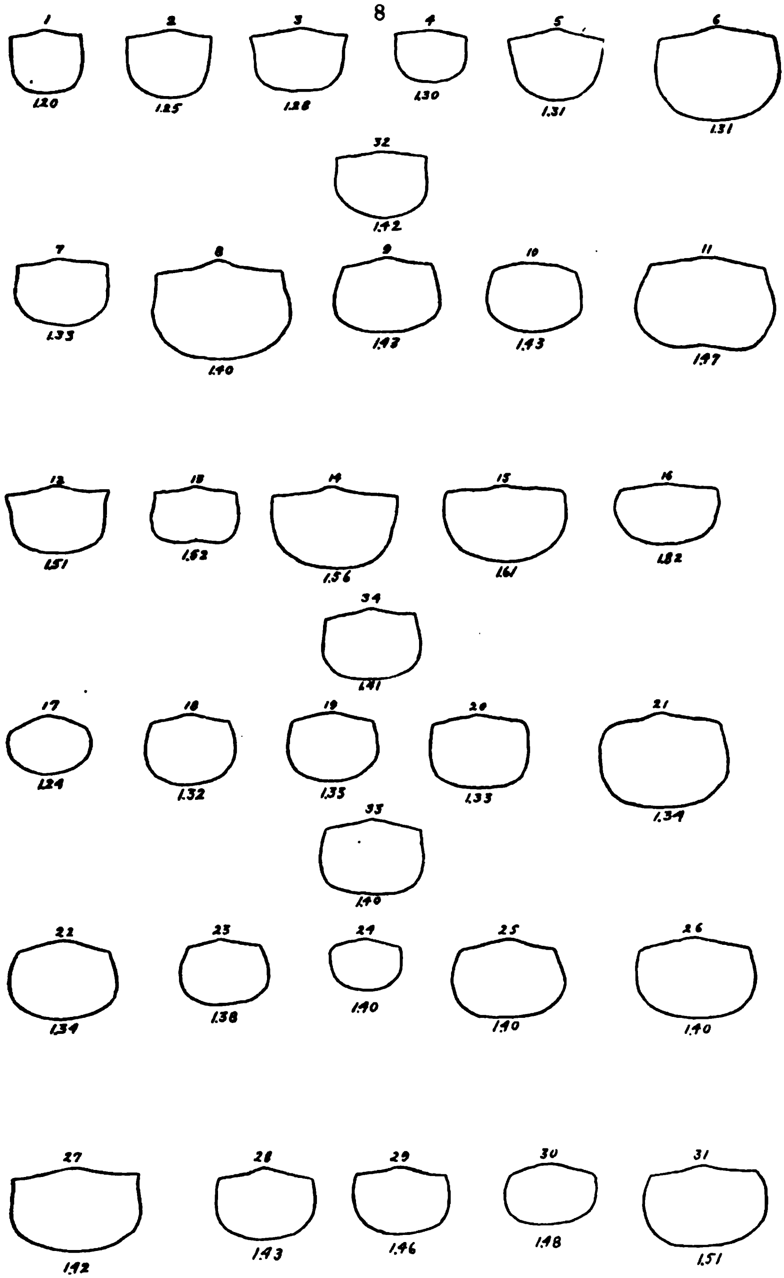

FIG. 8. *Platystrophia lynx.* 1-16, from Trenton Falls, N. Y.; 32, composite of 1-16; 17-31, from Colby County Kentucky (Trenton); 33, composite of 17-31; 34, composite of 1-31; Shell index given below each figure. All natural size. Collection Yale Museum.

Nos. 17-31 inclusive, fig. 8, represents the contours of a series of specimens from the Trenton of Kentucky (Colby Co.). Here the index varies from 1·24 to 1·51; the average being 1·4 and the largest class 1·4. The cardinal angle varies from 90° to 112° (in a specimen from Harrodsburgh, Mercer Co., Ky., the cardinal angle is 120°). The number of plications varies from 17 to 27; the number in the sinus from 3 to 5. No. 33, fig. 8, is a composite of Nos. 17-31 inclusive. This normal shell of the Kentucky group has an index of 1·40 and a cardinal angle of 95°. No. 34, fig. 8, is a composite of Nos. 32 and 33, and has an index of 1·41 and an angle of 93°. The great similarity of the New York and Kentucky forms is apparent.

8 *bis.*

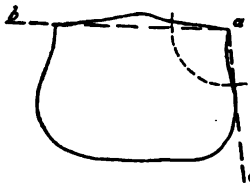

FIG. 8 *bis.* Diagram showing method of obtaining cardinal angle *bac.*

Very few specimens from the Trenton of Minnesota have been studied, but these show no departure from the above type. The specimens from the Galena of Minnesota are however more like the Cincinnati group *lynx.*

In brief, the Trenton shell is rather transverse, slightly shorter on the hinge than farther forward; valves about equally convex, never extremely gibbous; plications about 22, of which three or four are in the sinus, four or five on the fold. The sinus is never as profound as in the varieties *costata*, *laticosta* and *acutilirata.*

The Trenton forms just described are from the middle and upper part of the series. Some specimens from Montreal, Canada, loaned me by Mr. Chas. Schuchert, are of a somewhat different and more primitive type. These latter (fig. 9) have

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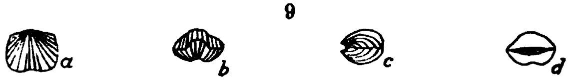

FIG. 9. *Platystrophia lynx*, small pauciplicate form from the lower Trenton at Montreal, Canada. *a*, ventral; *b*, anterior; *c*, profile; *d*, posterior views. Schuchert collection.

but 4–7 plications on the slopes; the shell is narrowest at the hinge-line and considerably less transverse than the Trenton Falls type (the index is 1·23 in the specimen figured, which is about an average individual). The second and third plications of the sinus arise about 4^{mm} from the beak. These shells strongly suggest the small pauciplicate form found at the base of the Lorraine at Cincinnati, Ohio.* As to the exact age of the beds from which these specimens came it is impossible to say. In

*See Winchell and Schuchert, Geol. Minn., iii, 1893, p. 456.

the section at Montreal, given in the Geology of Canada, "*Orthis lynx*" is listed from the first, second, and fourth divisions of the section; that is from the lower 150 ft. of the formation. The chances are that the present specimens are from the lowest of these divisions, or less than 10 ft. above the Black River formation.* These small shells may therefore represent the immediate ancestors of the normal Trenton form above described.

The small pauciplicate *P. lynx* (fig. 9 *bis*) from the lower Lorraine at Cincinnati, is of interest as the immediate progenitor of *P. costata* and probably also of *P. laticosta.* It occurs, associated with the uniplicate form (*costata*), often in clusters, one of which is shown in fig. 9 *bis*. This specimen has the shells in their natural position, with the beaks very closely appressed to the surface of support. The individual at the top of the figure is wedged in so closely between the adjacent branches of the *Constellaria*, as to indicate that the two valves never gaped more than very slightly indeed.

9 *bis*.

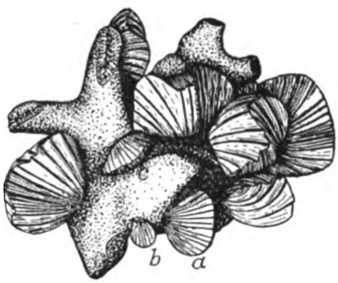

FIG. 9 *bis*. Cluster of *Platystrophia lynx*, pauciplicate form, on a colony of *Constellaria constellata*. All the individuals are in their natural position with the beaks closely appressed to the surface of support. *a* and *c*, *Plectorthis plicatella*; *b*, *Zygospira modesta*. Collection of the Museum of Comparative Zoology, Harvard University.

The question arises whether this form of *P. lynx* is not an unmodified descendant of the Montreal type just described. This is certainly possible if not probable. The occurrence of an occasional individual with few plications among the normal *P. lynx* of the middle and upper Trenton suggests, on the other hand, that these lower Lorraine forms may have originated as a variant of the latter. For convenience this form of *P. lynx* may very well be called *pauciplicata.* It seems, as stated above, to represent the initiation of a tendency that afterwards in *P. laticosta* and *P. costata* assumed considerable importance.

In American literature the Trenton shells have often been referred to the species *biforata.* I have already pointed out the fact that this type is not represented in American Ordovician deposits above the basal Trenton. The large form from the Cincinnati group universally known as *Platystrophia lynx* probably differs from the Russian *lynx* and is identical with our Trenton forms. In the interval between the Trenton and Lorraine the typical *lynx* changed surprisingly little. Fig.

*Geol. of Canada, 1863, pp. 137–138.

10, *a*, is drawn from an individual which departs very little from the normal form of the Lorraine.* Fig. 10, *b*, is an average specimen from Trenton Falls, N. Y., enlarged to the same size. The two shells have the same index, nearly the same number of plications, and differ little in contour. The cardinal angle of the Lorraine specimen is 89°, that of the Trenton Falls specimen 96°. The latter is more gibbous. It would

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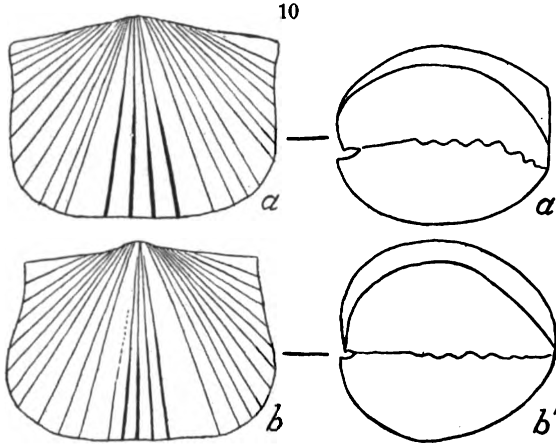

FIG. 10. *Platystrophia lynx.* *aa'*, normal Lorraine type from Vevay, Indiana, natural size; *bb'*, normal Trenton type from Trenton Falls, N. Y.; ×2½. *a*, author's collection; *b*, collection of Mr. Wm. L. Porter.

be possible to select plenty of adult individuals from the Trenton and Lorraine that except for size would present no appreciable differences. The slight change of the average shell index (from 1·4 in the Trenton specimens to 1·3 in the Lorraine (Vevay) specimens) is due solely to the more robust growth of the latter, which always have the higher index in early ephebic stages (see fig. 13). It will be shown later that the extreme manifestation of this tendency produces in the upper Lorraine a shell of very low index; while the latest representatives of *lynx*, now to be described, have again a very high index.

In the extreme upper part of the Ordovician (Madison beds) of Richmond, Weisburg and Laurel, Indiana, the writer found a variety of *Platystrophia lynx* which is of exceptional interest (fig. 11). As is well known, the so-called Richmond beds (*Rhynchotrema* zone) contain exclusively the variety *acutilirata* associated almost constantly with *Hebertella occidentalis*. At about 50 ft. below the Clinton at Laurel and about 13 ft.

* This specimen is from Vevay, Indiana.

to 15 ft. at Richmond, comes in a large and decidedly transverse variety of *P. lynx* associated with *Hebertella sinuata*.* This association is a point of great importance since it shows that these two forms of *Platystrophia* and *Hebertella*, so constantly met with together in the Lorraine, have lived on together at some point through the *Rhynchotrema* hemera† and here under a recurrence of suitable conditions reappear, the former with some modification, the latter with scarcely any.‡

This form of *Platystrophia lynx* has eight to eleven plications on the lateral slopes, and the index may be as great as 1·9.

11

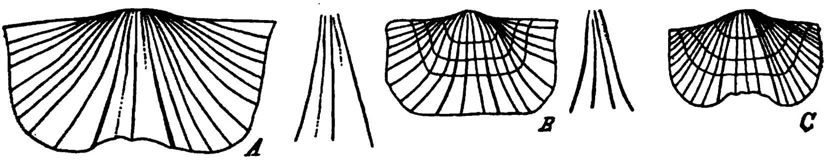

FIG. 11. *A*, *Platystrophia lynx* from 12 ft. below the Clinton at Richmond, Indiana; dorsal valve showing obsolescence of both lateral plications toward the anterior margin. *B*, dorsal valve of another individual from the same horizon and locality showing complete reduction of the fourth plication. *C*, specimen of *P. acutilirata* from the extreme Upper Ordovician at Weisburg, Indiana, showing the similarity of this retrogressive form to *P. lynx*. Author's collection.

A number of individuals (5 out of 100) show a reduction of the lateral plications of the fold and sinus. Fig. 11, *A*, shows a reduction of both lateral plications of the fold. On the anterior portion of the fold, the one to the right has completely vanished and the one to the left is very faint and does not reach the margin. All four plications are about normal on the posterior portion of the fold. Another specimen, fig. 11, *B*, has three plications on the fold. The only indication of the fourth is the abnormal breadth of the right hand plication at the umbonal region.

That such a tendency to eliminate plications should affect 5 individuals out of 100, while in the Lorraine not more than one *P. lynx* out of a thousand exhibits anything analogous, is certainly not without profound significance. There are in the

* These beds are exposed at Richmond near the point where the "Boston Pike" crosses Elkhorn Creek, S.E. of the city. The ledge of Clinton 12 ft. thick forms a fall. Immediately below the Clinton is 4 ft. of clay and below this, limestone layers alternating with shale. *Platystrophia lynx* is found in large numbers in the limestone for some distance down the creek.

† Buckman's term, or some other equally unequivocal, is needed in a case like this where the lifetime of a species is referred to. See Quar. Jour. Geol. Soc., xlix, 1893, p. 481.

‡ The Rhynchotrema zone does not contain any specimens of *Hebertella sinuata* except at its very base.

present collection two specimens of ***Platystrophia lynx*** from Vevay, Indiana, both of which have three plications on the fold: One individual has four in the umbonal region; and the other never developed but three* at any stage. The first has an abnormally low index (1·1) and bears every evidence of lateral cramping during growth. This would account for the failure

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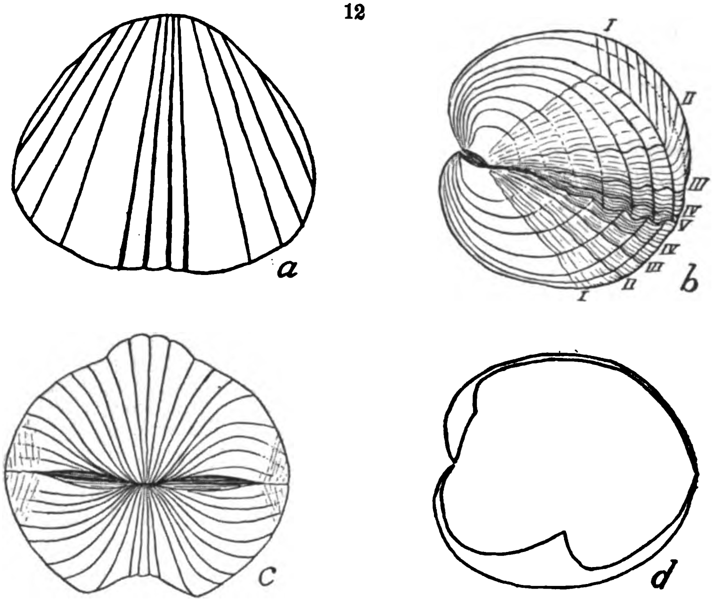

FIG. 12. Markedly gerontic individual of *Platystrophia lynx* from the "lynx beds" of Cincinnati, Ohio. Normal adult growth ceased at varix No. *I*. Note the very large cardinal angle (125°), extreme gibbosity, and obsolescence of the lateral plications. Dyer collection, Museum of Comparative Zoology, Harvard University.

of the fourth plication. The early growth stages of the second specimen also show an abnormally low index and the failure to develop the full number of plications is therefore probably due to the same cause. The Richmond shells, on the other hand, are very transverse at all stages, especially so in the adult. The correct explanation of the obsolescence of plications in this type, as well as in the *laticosta* and *costata* types where it is still more pronounced, is probably to be sought in a readjustment of the brachia, producing an elevation and narrowing of the fold. This subject will be more fully discussed in a later paragraph.

*** Both are strictly of the triplicate type.**

Gerontic stages of Platystrophia lynx.—The gerontic stages of this species are alluded to above. In the "lynx beds"* at Cincinnati, Ohio, there is a veritable race of gerontic individuals. Fig. 12 represents one of these (from the Dyer collection of Harvard). The hinge-line is relatively very short, the cardinal angle being 125°. The vertical diameter exceeds the longitudinal in the ratio of 102 to 100. The shell index is 1·16; so that the three dimensions of length, breadth, and height are nearly equal. This extreme gibbosity, combined with so short a hinge-line, produces the peculiar effect seen in fig. 12, *a*; that is, though a similar view of *P. lynx* usually shows all the plications of the slopes, in this case only five out of eight are visible on each slope. Normal adult growth was reached at the varix numbered *II*. After this point the increase was mainly in a direction at right angles to the plane of separation of the valves. This has produced such a degree of incurvature of the beaks that the delthyria are completely concealed, and since there is in this individual no encroachment of the pedicle upon the ventral beak, this organ must have been reduced to very small dimensions or possibly have ceased to function at all. The changing contour of another individual, in which gerontic stages are initiated early in the ontogeny, is shown in fig. 13, of a specimen from Vevay, Indiana. *b–g* show these successive stages separately drawn.

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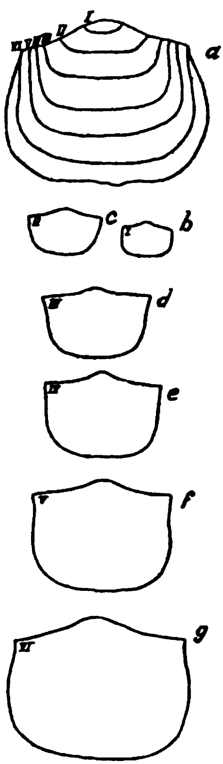

FIG. 13. *Platystrophia lynx* from the upper Lorraine, Vevay, Indiana, showing growth varices (*I–VI*) of a gerontic individual and the successive stages drawn separately (*b–g*). Author's collection.

The initiation of gerontic stages early in ontogeny is clearly indicative of the paracme of this type of *Platystrophia*. One of the most extreme manifestations of senescence is the obsolescence of the plications; yet in the present group this begins comparatively early (fig. 12, *b I*) and in later stages the 1st, 2d, 3d and 4th plications from the cardinal angle have completely disappeared and the shell is non-plicate, except at the front margin; and even here the plications are inconspicu-

* See Nickles, Jour. Cin. Soc. Nat. Hist., vol. xx, No. 2, Jan. 1902, pp. 85, 86.

ous. Another feature indicative of extreme senescence is the thickening of the shell. This has advanced to such an extent in many specimens from the "lynx beds" that the space available for the lodgment of the internal organs of the animal is less than in earlier growth stages. In one specimen, fig. 14, *C*, there is a very exceptional thickening of the ventral valve over the anterior margin of the ovarian region. In all cases of great thickening of the shell the muscular pit of the ventral valve is profound and the shell substance at its bottom is often so thin as to be translucent. Fig. 14, *B*, shows one of the most massive shells seen. This shell is 12^{mm} thick at the anterior rim of the muscular pit. Six laminæ parallel to the outer surface of the shell (corresponding to as many strong growth varices) indicate the successive additions to the shell substance. After the first (lowest) of these no forward growth took place, and there was a progressive reduction in the amount of room inside the shell.

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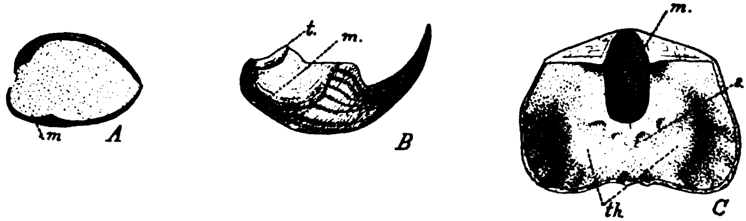

FIG. 14. *Platystrophia lynx*. *A*, from Vevay, Indiana; *B* and *C*, from Cincinnati, Ohio, all slightly reduced. *A*, normal adult individual cut antero-posteriorly in the median plane to show normal thickness of valves; *m*, muscular platform of ventral valve. *B*, extremely senile and greatly thickened ventral valve, showing lamination of shell substance and six successive additions on its inner surface after normal adult growth had been attained; *t*, tooth; *m*, muscular pit; *C*, greatly thickened ventral valve, interior view showing profound muscular pit, *m*; vascular impressions, *s*; and abnormal thickening in the ovarian region, *th*. *A*, author's collection; *B*, collection of Yale Museum; *C*, Dyer Collection, Museum of Comparative Zoology, Harvard University.

There is no evidence that this gerontic type of *lynx* extended its range beyond the "lynx beds," or that it produced any radical from which a new orthid stock sprang. It seems to have become extinct. The succession, so far as concerns the remain-

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FIG. 15. *a-e*, *Platystrophia lynx var. laticosta* from the Lorraine, Vevay, Indiana. *a-a'''*, anterior, ventral, posterior, and profile views of the form *unicostata*, in which the lateral plications of the fold and sinus are completely lost; *b-b'''*, same of an individual which has one lateral plication feebly developed; *c-c'''*, same of an individual in which the lateral plications of fold and sinus are present only in the umbonal region; *d-d'''*, individual with one complete lateral plication; *e-e'''*, normal *laticosta* type. *f-f'*, tracing from Pander's figure of *P. costata*; *g-g'*, tracing from Meek's figure of *P. dentata*; *h-h'*, tracing from deVerneuil's figure of *P. chama*. *a-e*, author's collection.

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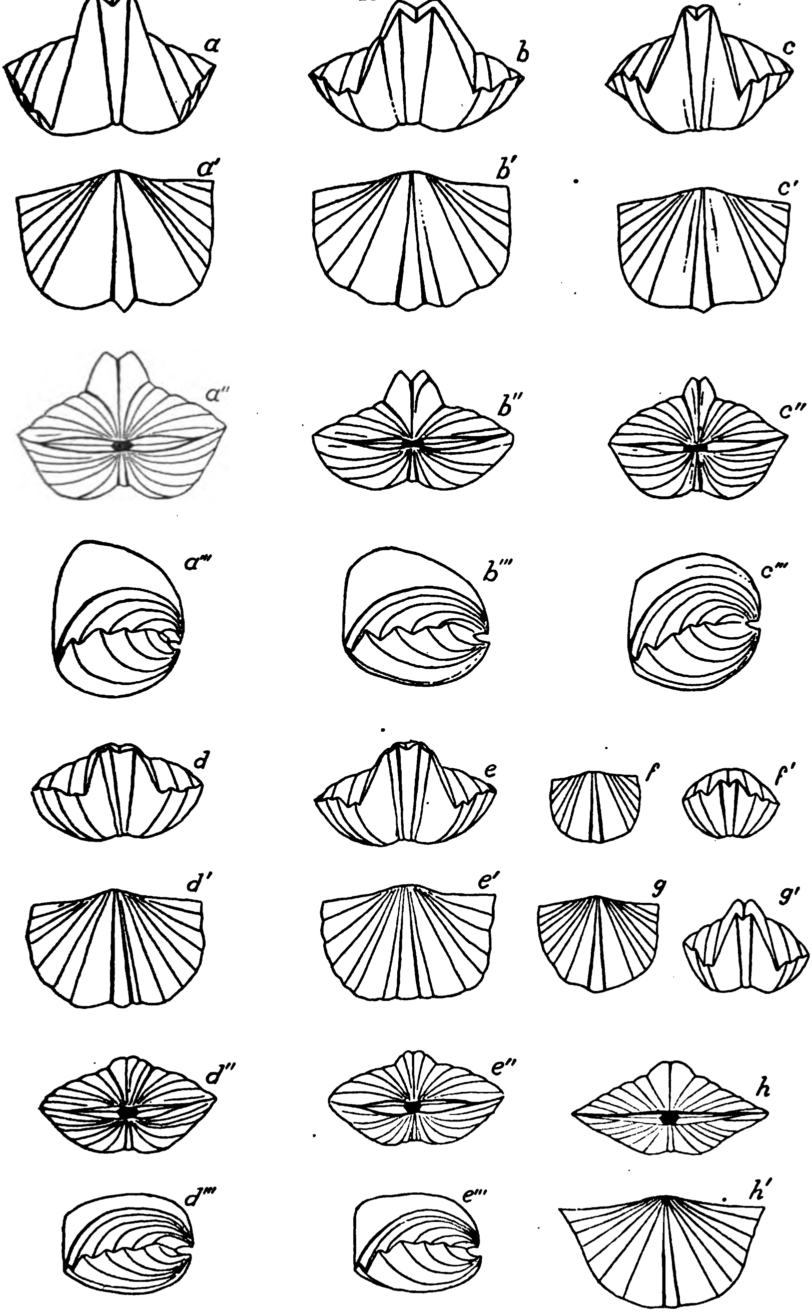

(*See bottom of page 28 for description.*)

der of the Ordovician of this country was, as we shall see, taken up and passed on by the *laticosta* and *costata* types.

The fact that a more nearly normal form of *lynx* survived to the close of the Ordovician (Madison beds) has already been pointed out. This form seems to represent the final expression of the type—a shell, primitive in many respects, though of large size; and undergoing a last attempt to accommodate itself to changing conditions.

*Platystrophia laticosta.**—This is one of the most interesting and one of the least understood types of *Platystrophia.* It seems to be confined to American faunas, and occurs here only in the Cincinnati group of the Ohio valley, where it ranges through the Lorraine and reappears at the base of the Richmond formation.

Meek† has admirably described this variety and little can be

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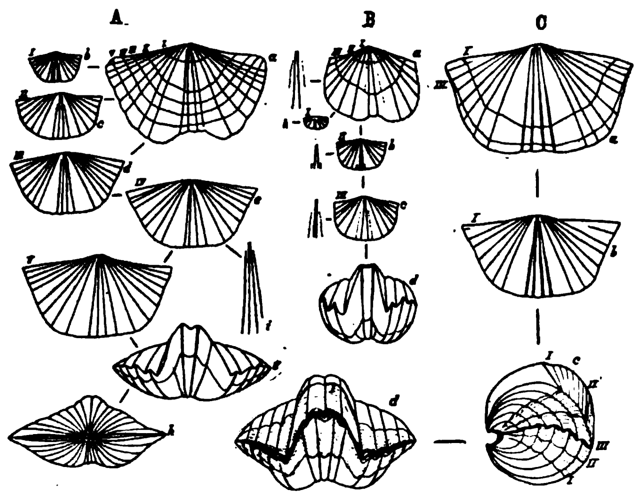

FIG. 16. *A* and *C*, *Platystrophia laticosta* from Vevay, Indiana; $\times \frac{2}{3}$. *B*, *P. costata* from Cincinnati, Ohio: $\times \frac{2}{3}$. *A*, shows growth stages *I–V* separately drawn (*b-f*), and anterior (*g*) and posterior (*h*) views: note the disappearance of the right hand plication of the sinus after stage *V*. *B*, shows the initiation of a second and third plication in the sinus at stage *II* (*a*, *b*) and their disappearance at stage *III* (*a*, *c*). *C*, is a gerontic individual of *P. laticosta*; note the increase of the cardinal angle after stage *I*, and the reduction in the height of the fold, and strong growth varices (*c*, *d*). *A* and *C*, author's collection; *B*, Yale collection.

added in regard to its adult characters. Its minute study, based upon hundreds of individuals, has, however, developed unsuspected relationships, which I shall now point out. Fig. 15 gives

* James, Cat. L. Sil. Foss. Cincinnati Group, 1871, p. 10.

† Pal. Ohio, i, 1873, p. 116, pl. 10, fig. 4. *P. chama* deVerneuil (not *P. costata* Pander) may be related to *P. laticosta*.

some idea of the variation of *laticosta*; *e* is a normal individual with one large (median) and two small (lateral) plications in the sinus. *a* has but one plication in the sinus and the fold is extremely elevated. *b* to *d* are intermediate between these two. In seeking the derivation of this type as in other types of *Platystrophia* the growth stages are of paramount importance. In fig. 15, *c*, are shown two lateral plications in the sinus originating at the usual distance from the beak but disappearing a little over half way from the beak to the front margin. Fig. 16, *A*, shows the inception of this process of reduction of the lateral plications of the sinus. Here only one plication is affected, and that only near the front margin. Fig. 16, *B*, shows the same tendency in *P. costata*.

Considering now the growth varices (fig. 16) it is evident that *laticosta* becomes progressively more transverse during ephebic stages, while *costata* becomes progressively less transverse; the early stages of the two being identical and also identical with the early stages of *P. lynx*. In *P. laticosta* the cardinal angle is progressively 72°, 73°, 63°, 68°, and 70°, returning thus in gerontic stages to near the angle of an early ephebic stage. In *costata* (fig. 16. *B*) the angle changes from 95° to 78° to 82° to 99° in the fully adult stage, while in gerontic stages it may be as much as 113°. The largest angle seen in any stage of *laticosta* was 95°. Both *laticosta* and *costata* are therefore derived from a primitive *lynx* by a reduction of the number of plications, and an elevation of the fold. The relation of *laticosta* to *costata* is not a linear one; but after the establishment of a pauciplicate stock like the young of both (see ante), a divergence occurred, one branch taking the direction of an elongate narrow type (*costata*) and the other the direction of a transverse acuminate type with extremely high fold (*laticosta*).

The above mentioned uniplicate *laticosta* (fig. 15, *a*) is found in the Upper Lorraine and is not to be confused with *P. costata*. The former has an exceptionally high fold but the same contour as a normal *laticosta*, from which variety it is derived, and with which it is connected by every possible gradation. If it is desired to distinguish this form from *P. laticosta*, it may conveniently receive the name of *unicostata*.*

In the *Dalmanella Meeki* zone which intervenes between the Lorraine and Richmond beds, no specimens of *Platystrophia* occur, except at the very top of the zone where the typical

* The *dentata* and *crassa* of American authors undoubtedly include these two forms *costata* and *unicostata*. The former term will be shown to apply only to certain foreign and Upper Silurian biplicate types. Since the term *crassa* confuses two distinct forms it had better be abandoned altogether, especially since the form to which it was intended to apply is the *costata* of Pander.

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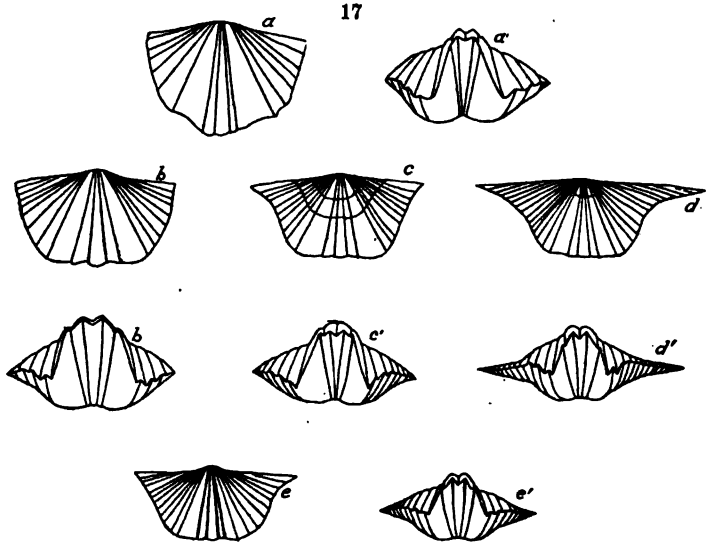

FIG. 17. Group of *Platystrophia acutilirata* from the base of the *acutilirata* zone (Lower Richmond) Tanner's creek, Indiana, with forms transitional to *P. laticosta* from the same zone. *aa'*, *P. laticosta*, after Meek; *bb'*, *P. laticosta*, Tanner's creek, lower Richmond; *cc'*, intermediate *acutilirata* type; *dd'*, very mucronate *acutilirata*; *ee'*, normal *acutilirata*. Author's collection.

laticosta again makes its appearance. Within the next 20 ft. of strata this *laticosta* is modified into a typical *acutilirata*. Fig. 17 will make this clear. *The transition has been noted in so many individuals, from so many different localities, that there can be no doubt as to the correctness of this view of the relationship of these two forms.* If any additional evidence were needed, it is furnished by a study of the early stages of *acutilirata* and by the general angularity and high fold of the latter species; as well as by the absence of the *laticosta* type from the *Rhynchotrema* zone, where *acutilirata* abounds.

Few individuals of *laticosta* present pronounced gerontic modifications. Such changes when they do occur produce a shell of extreme gibbosity, and with a large cardinal angle (from 65° to 74° in one specimen), so that the contour of the shell approaches that of *P. lynx*. Fig. 16, *C*, illustrates this. Normal growth ceased at stage *I*: the fold subsequently becomes lower relative to the size of the shell (cf. stages *I* and *II*), and the frontal profile becomes regularly curved instead of being truncated as in ephebic stages (cf. fig. 16, *Cc*, with fig. 15, *e'''*); so that the profile also resembles that of a gerontic

P. lynx. In fact the gerontic *laticosta*, in almost every feature in which it departs from the normal adult type of the variety, approaches *P. lynx.*

In another place* I have pointed out the intimate connection between *Platystrophia laticosta* and *P. lynx.* The examination of many thousands of specimens of these forms has failed to bring to light any character which does not show transitional stages from one to the other. The relatively greater strength and smaller number of the plications of *laticosta* is its most constant character, and with this is usually combined auriculation and prolongation of the cardinal extremities: the latter character is, however, by no means uncommon in *P. lynx.* It seems best therefore, to the writer, to consider *laticosta* as a variety of *lynx*, transitional between it and the species *acutilirata.*

For comparison with the uniplicate *laticosta* I have inserted (fig. 15, *h*) figures of *P. chama* traced from deVerneuil's figures.† That author says (op. cit.) he succeeded in obtaining a complete series of transitional forms between the small narrow type of *chama* (= *costata* Pander) and the acuminate type figured. As I have not seen any specimens of *P. chama*, deVerneuil's statement must be taken as indicating the relation of these two forms; though I strongly suspect that *chama* may bear no closer relation to *costata* Pander than does the uniplicate *laticosta.* The latter may, indeed, be the form to which it more nearly corresponds.

Platystrophia acutilirata.‡—Another type, found only in American faunas, is *Platystrophia acutilirata* Conrad, which is confined to the Richmond beds of the Cincinnati group.§ This species presents the most remarkable similarity to a *Spirifer* of any of the types of *Platystrophia.* The breadth may become as much as three times the length; and the cardinal extremities are frequently as acuminate as those of an average *Spirifer mucronatus*,‖ yet between these extreme forms

* This Journal, July, 1902, p. 14.

† Géol. de la Russie, 1845, pl. v. figs. 1*b*, 1c.

‡ Conrad, Jour. Acad. Nat. Sci., Philadelphia, viii, 1842, p. 260.

§ Keyes lists this form from the Hudson shales (Cincinnati) of Louisiana, Missouri. As he gives no figure or description, it is uncertain whether his specimens are really referable to *acutilirata* or belong to the acuminate type of *lynx*. See Keyes, Geol. Missouri, vol. v, Paleontology, 1894, p. 66.

‖ Prof. H. S. Williams has called my attention to the fact that Atwater's specimen of *S. pennatus* came from a locality in Ohio to which examples of *Platystrophia acutilirata* might have been transported by streams. While I do not believe that *Spirifer pennatus* is a *Platystrophia acutilirata*, the possibility of this being the case together with the total inadequacy of Atwater's description and figures, would seem to warrant abandoning his name altogether and returning to the well known name of *mucronatus* for this species of *Spirifer*. See Atwater, this Journal, ii, 1820, p. 244, pl. I, figs. 2, 3.

and a normal *P. laticosta* there is, as above stated, *every possible gradation*, as there is between the latter and *P. lynx*.*

P. acutilirata presents considerable variation, chiefly, however, in becoming first progressively more and more acuminate, and second in becoming, in the upper part of its range, retrogressively less and less acuminate. The shell index varies in progressive series from less than 1·6 to more than 2·7 and in retrogressive series from the latter figure to 1·4. The number of plications varies from 18 or 19 to 37 or 38, of which three are almost invariably in the sinus (four on the fold).† The cardinal angle varies in progressive series from 80° to 40° and in retrogressive series from 40° to 90°, which is very nearly the normal angle for *P. lynx*. These changes may frequently be noted in a single individual. Fig. 18, *e*, shows a retrogressive individual from the upper Richmond beds of Richmond, Indiana.‡ This specimen is inequilateral through inequality of growth and not as a result of deformation after fossilization. Such lack of symmetry is frequently met with among these retrogressive individuals. The early ephebic stage (*I*) is almost identical with such a form as fig. 17, *b*. The normal *acutilirata* stage is shown at *II* (fig. 18, *d*, illustrates the same thing). The cardinal angle here changes from 76° in stage *I*, to 50° in stage *II*, back to 77° in the final stage (using the right-hand angle in each case). Fig. 18, *f* to *k* with the degrees marked to the right, indicate the changes for other individuals. Fig. 18, *k*, represents a specimen from the lower part of the range of *acutilirata*.§ Here all the stages are progressive,

* Prof. D. W. Dennis has called attention to the change from narrow to greatly extended forms of *P. acutilirata* in traversing the Richmond section from the foot to the head of the gorge of the Whitewater river. He did not, however, recognize the relation of *acutilirata* to *laticosta*. Dr. Dennis also calls attention to the variation of *Hebertella* in the same section. I have already mentioned the presence of *H. sinuata* in the upper part of the Richmond section. This species is also found at the base of the Richmond beds and is there modified into the variety *occidentalis*. The latter is not however modified back into a *sinuata* but this form comes in suddenly at the top of the section. See Proc. Ind. Acad. Sci., 1898, pp. 288, 289.

† Meek says the breadth is "sometimes twice, or even, in extreme cases, three times the length of the valves;" and that there are "on each side of the mesial fold and sinus from 11 to 18 [plications], making the entire number about 26 to 40 on each valve." I see no reason to doubt his extreme figures. See Meek, Pal. Ohio, vol. i, 1873, p. 119.

‡ The retrogressive forms of *acutilirata* figured in this paper are nearly all from the falls of the west fork of the Whitewater river, one mile N.W. of Richmond. These beds come stratigraphically immediately below those of Elk Horn creek, mentioned above as containing a peculiar type of *P. lynx*. The latter beds are not exposed on the west fork. Fig. 11, *c*, is from equivalent strata just south of Weisburg Station, Ind.

§ This specimen is from Tanners creek, Dearborn Co., Indiana, one mile S.E. of Weisburg. It is associated with *Prasopora hospitalis*, *Batostoma varians*, *Leptæna rhomboidalis*, *Strophomena planumbona*, *Rafinesquina alternata*, a very convex form, and a very large form, *Hebertella sinuata*, *Streptelasma corniculum*, etc., etc.

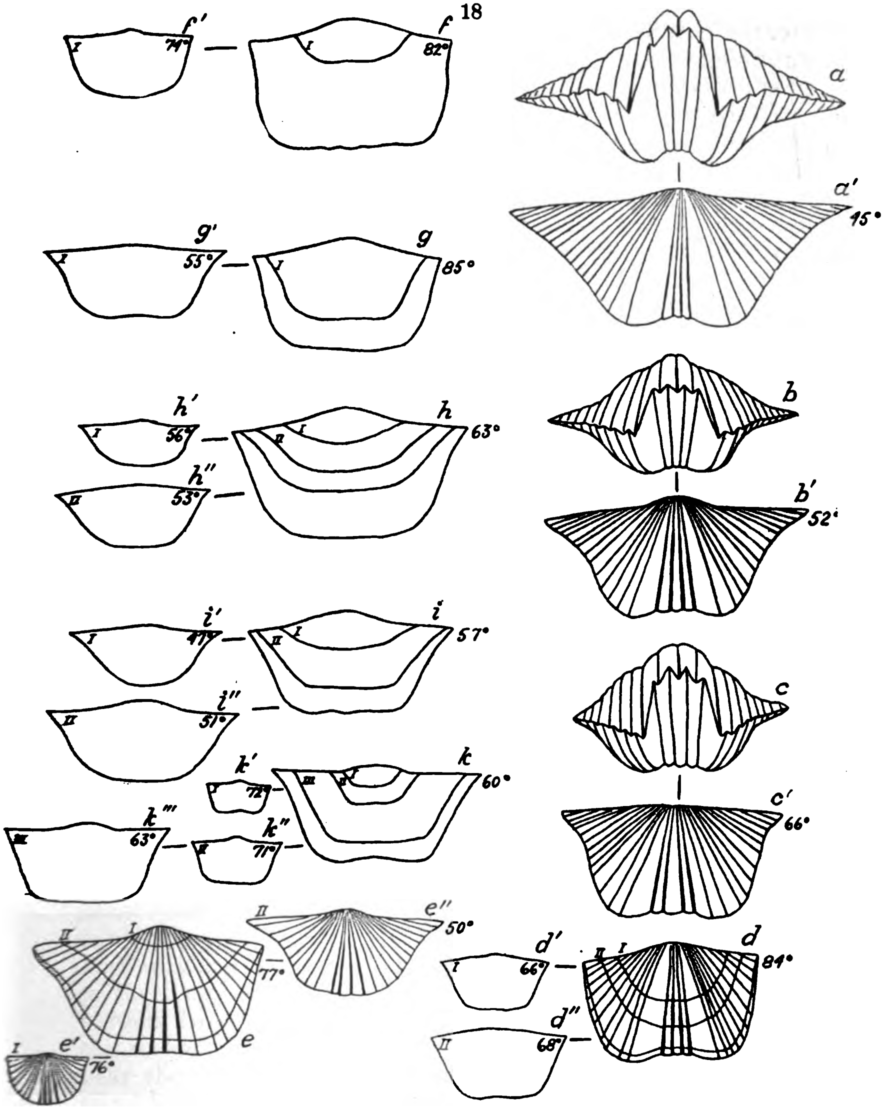

FIG. 18. *Platystrophia acutilirata* from Richmond, Indiana. *a-a′*, anterior and ventral views of a very mucronate individual; *b b′*, an intermediate form; *c-c′*, narrower, very gibbous form; *d-d″*, retrogressive type with stages *I* and *II* drawn separately to the left; *e-e″*, a similar individual showing asymmetrical growth and great increase of the cardinal angle in late growth stages; *f*, *g*, *h*, *i*, outlines of other retrogressive individuals showing increase of the cardinal angle in late growth stages; *k-k‴* an individual from the base of the *acutilirata* zone showing progressive decrease in the cardinal angle. Specimens *a–i* are from the upper part of the *acutilirata* zone. Author's collection.

i. e. the individual becomes more and more acuminate throughout its ontogeny. What is true of this individual is true of practically every individual from the same horizon.

Platystrophia acutilirata presents the most profound gerontic modifications of any member of the genus; and gives rise in even greater degree than *P. lynx* to what may almost be termed a phylogerontic group of shells representing the paracme of the *laticosta* line, of which as we have seen *acutilirata* is but an extreme manifestation. Though *P.*

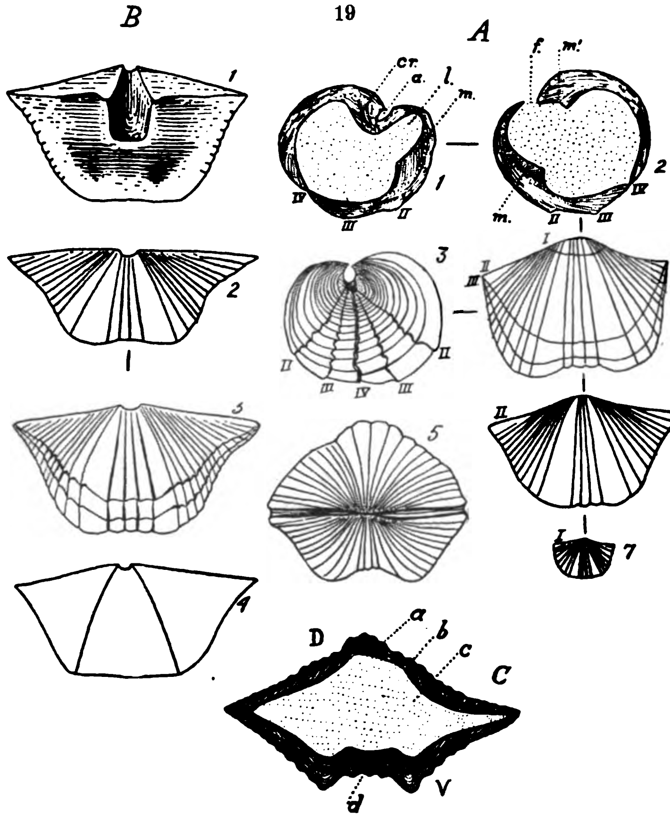

Fig. 19. Senile individuals of *Platystrophia acutilirata* from the upper Richmond of Richmond, Indiana. *A*, an extremely gibbous and greatly thickened shell; 1 and 2, median sections showing thickening and reduction of body cavity; 3, 4, 5, profile, ventral, and posterior views showing pronounced varices *II*, *III*, *IV*; 6 and 7, stages *II* and *I* separately drawn. *B*, another individual; 1, interior showing profound muscular pit; 2, stage represented by first growth varix; 3, ventral valve showing strong varices; 4, stage represented by second varix. *C*, another individual cut transversely in the dorso-ventral plane to show thickening of shell. *cr.*, crura; *a.*, area; *mm'.*, ventral and dorsal muscular platforms; *f*, pedicle foramen; *a*, normal and *b*, senile thickening of shell; *d*, ventral muscular platform. Author's collection.

acutilirata is a much smaller shell than *P. lynx* of the Lorraine, yet the thickening of the shell in gerontic stages is greater both relatively and absolutely. The acuminate cardinal extremities are so thickened that this region of the shell becomes practically filled up with shelly deposit. The thickening of the central and anterior region of the shell is very great (fig. 19, *A*, 1 and 2), so that the actual room left for the lodgment of the soft organs of the animal is less than in unthickened shells of a much lower index, and less both relatively and absolutely in gerontic stages than in ephebic stages of the same individual. Fig. 19, *C*, of a vertical section from cardinal angle to cardinal angle of a markedly senile individual, will make this plain. The convexity (vertical diameter) of the shell is also considerably greater than in any other type of *Platystrophia*, the height being in extreme cases 1·5 greater than the length, while in *P. lynx* the extreme is 1·04 or height and length nearly equal, and in *laticosta* 1·14. The changes in contour due to senescence are profound, as has already been pointed out. Fig. 19, *A*, represents a shell in which normal growth was attained at the varix numbered *II*. The cardinal angle at this stage is 58°. In the latest stage it is 79°, and in the early stage represented at *I*, it is 76°. Here is a total change of 39°.

The retrogressive series mentioned above is produced by the acceleration of gerontic stages, till in such individuals as fig. 11, *C*, from the extreme upper Richmond beds at Weisburg, Indiana, the acuminate or normal *acutilirata* stages come on near the beaks and the adult has the outlines of a normal *lynx*. In fact, the resemblance between this shell and the true *lynx* of the same horizon is so striking, that only by a study of the stages indicated by the growth varices can they be distinguished.

Whether any Silurian Orthid was derived from *Platystrophia acutilirata* is impossible at present to determine. Certainly none of the Silurian forms of *Platystrophia* bear any close relation to this type, since they are as persistently biplicate as the latter is persistently triplicate. To be sure, many individuals from the upper Richmond beds have one or other of the secondary plications of the fold and sinus originating very near the apex, as we should expect from the marked acceleration of these shells in nearly every particular; but I have never seen a specimen in which the lateral plications manifested any tendency to disappear, nor in which there is even a suggestion of a biplicate type. The form seems to have perished very soon after its assumption of retrogressive characters. Indeed, the coming in of a strongly molluscan fauna in these late Ordovician beds seems to indicate some radical change in con-

ditions and this may account for the sudden decline and extinction of *acutilirata.*

As to the taxonomic value of the term *acutilirata* the writer is of the opinion that the form should certainly be considered as a species, although, as pointed out, it is perfectly connected by intermediate forms with *P. laticosta*. It is not, however, except in a very limited zone associated with the latter variety; and it represents such a remarkable distinctness and completeness of history after its initiation, that no one need confuse it with any other member of the genus.*

Platystrophia costata.†—It will not be necessary to enter here into the question of the synonomy of this type. DeVerneuil's objection to Pander's name was based upon the preoccupation of the term *costata* by *Spirifer costatus* Sowerby. Since the latter is a true *Spirifer* we must return to Pander's name for the present form.

Platystrophia costata (=*P. dentata* Meek; *P. crassa* James) makes its appearance in American faunas in the lower Lorraine of the Ohio Valley; and is the well known variety with a rather small, gibbous shell having one plication in the sinus and five or six on the lateral slopes. The derivation of this type has been discussed at sufficient length under the head of neanic stages of *Platystrophia.* It comes from a normal triplicate type by the dropping out of both secondary plications of the fold and sinus.

Under *P. laticosta*, mention was made of a uniplicate form of that variety. Doubtless the latter has usually been confused

*It may seem to be doing violence to taxology to distinguish a form at one stage of its history as a *variety* and at another stage as a *species under a distinct name;* nevertheless, I believe we must be prepared to take this step, since we must certainly find as the investigation of fossils becomes more minute and precise that cases such as this of *Platystrophia laticosta* and *P. acutilirata* are by no means exceptional. In this connection I may quote a passage from a timely article by Mr. O. F. Cook on categories of species (Am. Nat., vol. xxxiii, 1899, p. 292). He is comparing existing species to islands and bodies of land more or less separated from each other in "the sea of non-existence." He says, speaking of incipient species, "Although the designation by name of the various prominences or arms of a diversified island [which is gradually sinking] is desirable, even before the expected separation occurs, the prophetic tendency should, in the interest of historical accuracy, be curbed to the extent of distinguishing in category between groups which are already segregated in nature and those which are not, ... by treating them as already distinct we ignore the existence of intermediate forms and proceed as though degree of apparent difference were an index of segregation or a taxonomic substitute for it." He suggests the use of the term *subspecies* for all such non-segregated groups or *incipient species.* In this sense *P. laticosta* would be a subspecies of *P. lynx;* and *P. acutilirata* the completely segregated group or species. I have retained the more usual designation of variety for the former.

† Pander, Beiträge zur Geognosie des russischen Reiches, 1830 p. 96, pl. 11, fig. 3.—De Verneuil, Géol. de la Russie, 1845, p. 140.—Sowerby, Trans. Geol. Soc. Lond., 2d ser., vol. v, pl. 55, figs. 5–7.

with *P. costata*. The two are, however, easily distinguished and, besides, have a different range.* *P. costata* is, moreover, derived from *P. lynx* and not from *P. laticosta*, as is the case with the other form.

Platystrophia costata presents well characterized gerontic stages (fig. 16, B). These are marked by extreme gibbosity and great breadth anterior to the hinge-line so that the cardinal angle may be as great as 113°. Where the secondary plications of the sinus and fold are faintly marked in ephebic stages, they are almost sure to become obsolete in gerontic stages. The thickening of the shell does not become pronounced as in *lynx* and *acutilirata*.

The *costata* and *laticosta* types seem to have been produced simultaneously from the same pauciplicate *lynx* stock. The former did not survive the Middle Ordovician either in this country or in Europe;† but from it sprang the only genus, so far as at present known, that can be traced to the *Platystrophia* group as a radical stock. From a study of the young of *Bilobites*, Beecher‡ concluded that it was probably derived from the *Platystrophia* group. This conclusion has since been called in question by Wysogorski,§ who maintains that the punctate character of *Bilobites* removes it from the "*Orthis* group," in which he places *Platystrophia*, and relates it to the "*Dalmanella* group." It is well known, however, that punctate and impunctate shells occur in a variety of diverse groups of Brachiopods, and that the early members of a group may be impunctate, while the later members are punctate.‖

The resemblance of the early nepionic stages of *Bilobites* to the nepionic stages of *Platystrophia* has already been pointed out. The similarity between a late nepionic stage of *Bilobites* and the adult *Platystrophia costata* amounts

* *Platystrophia cypha* James is doubtless this form of *P. laticosta*. He mentions the extremely high fold and one strong plication of the sinus. The writer has never seen as many plications as he records (22 to 26), but doubtless in the upper part of its range (his specimens are from Warren Co., Ohio), the form developed a larger number of plications. See James, Cin. Quar. Jour. Sci., i, 1874, p. 20.

† See Wysogorski, Entwicklungsgeschichte, p. 15.

‡ This Jour., vol. xlii, July, 1891, p. 54.

§ Entwicklungsgeschichte, p. 9, footnote 1.

‖ The early Spirifers are impunctate; but in the Ostiolati *S. plenus* is punctate. Among the derived genera several are punctate, viz., *Syringothyris*, *Cyrtina*, *Spiriferina*. Among the *Rhynchonellidæ* all the earlier forms are impunctate, but *Rhynchopora* of the Carboniferous is punctate, though in all other respects it agrees with the earlier Rhynchonellids. Among the *Athyridæ*, *Hindella*, *Cœlospira*, etc., of the Silurian are impunctate, while *Eumetria*, *Hustedia*, etc. of the Carboniferous, are strongly punctate; *Rhynchospira* is sparsely punctate. The *Atrypidæ* are impunctate. Among the Terebratulacea, nearly all are conspicuously punctate, but in the early genera, *Rensselæria* and *Amphigenia*, the punctation is incomplete. See Hall & Clarke, Pal. N. Y., viii, pt. 2, 1893.

In *Hebertella* the early species are impunctate or superficially punctate: *the upper Richmond form is more clearly punctate.*

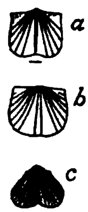

Fig. 20.—*a*, Young stage of *Bilobites varicus*, drawn from the beak of an adult individual, x 4: *b*, small specimen of *Platystrophia costata*, natural size; *c*, adult *Bilobites varicus*, natural size.

almost to identity in everything except size. Fig. 20, *a*, is drawn from the ventral beak of an adult *Bilobites varicus* from the Lower Helderberg of New York; and fig. 20, *b*, is a small individual of *P. costata*, from Cincinnati, Ohio. An examination of several hundred individuals of *B. varicus* has shown that there is invariably present, in well preserved material, a median plication at the apex of the ventral sinus* (fig. 20, *a*). This plication very soon becomes obsolete, so that the greater portion of the sinus is without plication of any kind. Clearly such a vestigial character is not without significance. The median plication of the sinus of uniplicate and triplicate types of *Platystrophia* is a character that is never absent whatever other modifications may affect the shell; the presence of this persistent character in a derived genus is to be expected, and affords, together with the evidence from development, a virtual demonstration of the derivation of *Bilobites* from *Platystrophia*. Moreover, since the *costata* and *unicostata* types of the latter genus present the most profound modifications of fold and sinus, and since this extreme elevation of the fold must have been related to a marked separation of the brachia and the latter character have been responsible for the production of a bilobate shell, we are justified in considering either *costata* or *unicostata* as the ancestor of *Bilobites*. *P. costata* is preferred because of its wide distribution and greater abundance. It would be interesting to know in what province the early stages in the evolution of *Bilobites* were passed. No trace of the genus has so far been found in the late *Ordovician*. It is extremely rare in the late Clinton and Niagara of this country; but occurs somewhat abundantly in the equivalent formations of the Island of Gotland. Since *P. costata* is abundant in the European province, we may look there rather than in America for the transitional forms to *Bilobites*.†

The taxonomic value of the term *costata* need not detain us long. De Verneuil regards *P. chama* as a variety of *P. biforata* (?), and in this country the form is also usually placed as a variety. It has been shown that there are in the Cincinnati group abundance of transitional forms between *costata* and the

* This characterizes all the other species of *Bilobites* as well.

† Mr. C. J. Sarle of Rochester, N. Y., has found a form of *Bilobites*, similar to *B. verneuiliana*, in the Clinton of Rochester, N. Y., where, in one layer, it occurs rather abundantly.

pauciplicate *lynx*. For the European form I can not speak. It may even prove to be distinct from ours, though it certainly seems to be identical. The wide distribution of *costata* would seem to entitle it to rank as a species, yet the evidence at present available is rather in favor of regarding it as a variety of *P. lynx*, the differentiation of which began quite early in the history of the genus.

Platystrophia biforata.—The reasons for considering this species as distinct from American Ordovician forms of *Platystrophia* have already been stated, and the main features of the type described. Little can be added in regard to the foreign forms. The Russian *biforata* occurs in beds as low as the Trenton, and in this country, a shell of quite similar aspect, and of unquestioned biplicate type, is found in the Trenton of the Lake Champlain region* associated with the normal *lynx* type.† This association is of great interest since it shows that the differentiation of these two species was going on in the early Ordovician, and also that there was free intercommunication between the American and European Province at that time.‡ The total absence of *biforata* from American deposits throughout the remainder of the Ordovician might also indicate a closure of this avenue of communication early in that period.§

In the Clinton of this country we again meet with a biplicate *Platystrophia* strikingly similar to the Russian *P. biforata*. The writer has examined about 50 individuals from Rochester and Gasport, N. Y., Dayton, Ohio, Irvine, Kentucky, and Richmond, Indiana. These present considerable variation, mainly in the number of plications, which may be all the way from 16 or 18 to 46 on the valve, a greater range than in any other type (see fig. 21).

* Mr. P. E. Raymond sent me specimens from the Crown Point section. The species occurs there in the upper part of the section. All the specimens sent may be of the biplicate type, although several have three plications in the sinus. The exfoliation at the beaks renders it impossible to make sure to which type the latter belong. Billings figures a Canadian *Platystrophia* with rounded cardinal angles and four plications in the sinus, two of which appear to arise at the apex. This specimen is very similar to several of the Crown Point forms, and may very likely belong to the same type. See Raymond, Bull. Am. Pal., No. 14, 1902, pp. 27, 28; and Billings, Geol. Canada, 1863, p. 167, fig. 149 *a*.

† Some specimens collected at Ft. Cassin, Vt., by Mr. H. M. Seeley, are clearly referable to *P. lynx*.

‡ See Frech, Lethæa geognostica, Theil I. Lethæa Paleozoica, 1897, 2, p. 100. Ruedemann, Bull. N. Y. St. Mus., No 42, vol. 8, 1891, pp. 561-564; Ibid., No. 49, 1901, pp. 104-107 and footnote p. 107. Ulrich and Schuchert, Bull. N. Y. St. Mus., No. 52, 1902, pp. 633-663.

§ Cf. Dana, Man. Geol. 4th ed., 1894, p. 536.—Ruedemann, Am. Geol., June, 1897, pp. 367-391.

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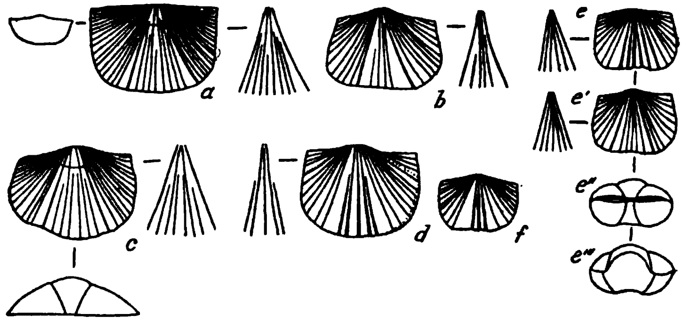

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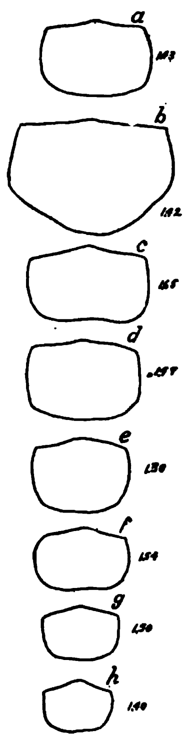

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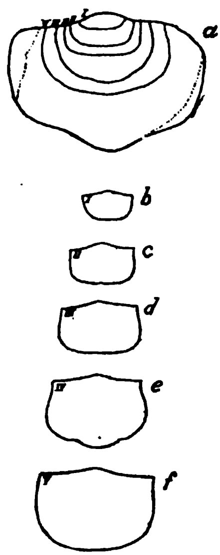

FIG. 21. *a, b, c, d, f, Platystrophia biforata* from the Clinton of Rochester, N. Y.; *a, b, c,* dorsal and *d, f,* ventral valves : adjacent diagrams show method of origin of plications of fold and sinus. *e, P. biforata* from Wesenberg, Russia (Ordovician); *e*, ventral; *e'*, dorsal; *e''*, posterior; *e'''*, anterior views. *a, b, c, d, f,* collection of Mr. C. J. Sarle, Rochester, N. Y.; *e*, Yale Collection.

FIG. 22. Series of Clinton *Platystrophia biforata* showing variation in outline and index. Value of index given to right of each shell. Collection of Mr. C. J. Sarle, Rochester, N. Y.

FIG. 23. Specimen of *Platystrophia biforata* from the Clinton of Gasport, N. Y., showing growth varices *I-V* and the stages separately drawn (*b-f*). Collection U. S. National Museum.

The number of plications in the sinus varies from two to nine (three to ten on the fold), which is also a greater range than observed in any other type. All except the primary plications originate at a considerable distance from the beak. The amount of variation in the shell index and contour (fig. 22) is less than in the *lynx* type, and the sinus is never profound. The average index is about 1·4, or very near that of the Trenton *lynx*. The cardinal angle is difficult to determine with accuracy owing to the worn condition of most of the specimens; but is scarcely ever less than 90° and may be considerably over 100°. The dorsal valve is usually considerably more convex than the ventral, especially in the umbonal region, but the incurvature of the beaks is not as great as in *lynx*. Internally *biforata* has the dental sockets more deeply excavated and the crura more prominent. The muscular scars have not been observed.

The British types of *Platystrophia* have given the writer considerable trouble because of the general absence of specimens of that province from American collections. The figures and descriptions given by Davidson and others throw very little light upon the subject. All their Wenlock examples certainly belong to the *dentata* type, as is pointed out later, but the position of the *Ordovician* forms cannot be determined. The var. *fissicostata* McCoy,* judging from the figures given by Davidson†, strongly resembles our Clinton forms. It has, according to McCoy, "four ribs on the rostral part of the mesial furrow, the two outer of which usually branch at four or five lines from the beak, the others branch irregularly lower down once or twice; lateral ribs varying from six to fifteen within three or four lines from the beak, branching irregularly, some into two, others into four, with age; surface crossed towards the margin with sharp striæ of growth. This variety does not seem to have been noticed either in Russia or America, yet it is extremely common in our old rocks . . . ." This variety, according to Davidson, "abounds in the Caradoc" at numerous localities and in the Coniston, etc. Now, the only American type known to the writer that ever has bifurcating plications is the *biforata* of the Clinton, in which group this peculiarity is common.‡ Again, the presence of "four ribs on the rostral part of the mesial furrow" is a character absolutely unknown in the *lynx* type, but common in the *biforata* type. On the whole, it seems likely that *fissicostata* is a true *biforata* similar to

* British Pal. Foss., 1852, pp. 192, 193.
† Silurian Brachiopoda, 1871, pl. xxxviii, figs. 15-17, 19.
‡ Mr. Foerste has already called attention to this fact. Bull. Dennison University, I, 1885, p. 80.

our Clinton forms.* The derivation of *P. biforata* has been discussed at some length in connection with *P. lynx*. It is plain that we must look to European deposits for the fullest light on this point. I am convinced that whatever new evidence arises will be found to support the position taken here, that *P. lynx* is really the more primitive. The history of the species after its reappearance in our Clinton faunas is not as fully understood as could be wished, owning to the small amount of careful stratigraphic work that has been done on this series of rocks. Too much emphasis can not be laid on the necessity of *accurate, detailed, and comprehensive* work of this sort. Nevertheless the main features outlined above are not likely to be modified by future investigations.

To *Platystrophia biforata* is here assigned the rank of a species occupying the same position of prominence in relation to the European and Silurian faunas that *P. lynx* does in relation to the American Ordovician faunas. So far as is now known, the type did not survive the Clinton.†

Platystrophia dentata.‡—So much confusion exists in this country in regard to this type of *Platystrophia* that it will be necessary to enter somewhat in detail into the question of synonomy.

In 1830 Pander described and figured *Porambonites dentata*, *P. costata*, *P. brevis*, and *P. recta*. The affinities of the last two are uncertain, but the first two represent very characteristic and widely distributed types of *Platystrophia*. *P. dentata*, according to both the figures and description given by Pander, has two plications in the sinus (three on the fold) and about five on each side. The sinus is deep, the contour of the shell rounded, and the profile plump, or even gibbous. This form was refigured and described by deVerneuil,§ who says that it passes by insensible gradations into *biforata* on the one hand and *chama* (=*costata*) on the other. Davidson‖ placed *dentata* in the synonomy of *biforata*. In 1873 Meek¶ described under this name a form which he says is "referred in Mr. James's list to *O.* [*Orthis*] *dentata* of Pander." In regard to this, Mr. James** says, the specimens "were wrongly put up

* According to Schmidt, *fissicostata* occurs in Russia at Muddis, Koil, Lyckholm, and Hohenholm, in the Lyckholm beds, which are equivalent in age to the upper part of our Cincinnati group. See Schmidt, Archiv. für die Naturkunde Liv.-, Ehst.- und Kurlands, 1ter ser, 2ter Band, 1te lieferung, 1858, p. 213.

† *Delthyris brachynota* Hall (Geol. 4th Dist. N. Y., 1843, p. 71) is a *P. biforata* of the Clinton type.

‡ Pander, Beiträge zur Geognosie des russischen Reiches, 1830, p. 96, pl. 11, figs. 4 a–e.

§ Géol. de la Russie, 1845, p. 138, pl. iii, fig. 5 a–f.

‖ Silurian Brachiopoda, 1871, p. 268.

¶ Pal. Ohio, i, 1873, p. 117.

** Cin. Quar. Jour. Sci., i, 1874, p. 21.

for Mr. Meek, Pander's *O. dentata* not being sent." It seems that Meek received the labeled specimens from James. The latter further says: "I now propose the above name [*crassa*] for the shell described by Meek [as *dentata* Pander]." Meek (loc. cit.) expresses grave doubts as to the identity of the form with Pander's species. He says: "I doubt very much, however, whether it agrees with that variety [*dentata*], which is described by McCoy, from British specimens, as having constantly two plications in the sinus." Nevertheless, Miller* subsequently referred the form to *dentata* without further remark. It is known now that Meek's *dentata* is the same as *crassa* James; and it has been pointed out that both are the same as *costata* Pander. The name *crassa* therefore lapses into the synonomy of *costata*.

Platystrophia dentata Pander is a perfectly distinct type found in the Ordovician of Russia and the Niagara of both Europe and America. To this type belong the Anticosti and Gotland forms, as well as the Niagara form of Kentucky and Indiana.

In regard to the variation of *P. dentata*, there is little to be said. Shaler's measurements of a series of twenty shells from Anticosti (which are now before me) show but little variation, and the same is true of the Gotland specimens, about thirty of which I have measured. There is also scarcely any variation in number of plications. One specimen from Gotland has three instead of two in the sinus, though only two start at the beak. The Kentucky specimens figured by Nettleroth also have at the front margin more than the usual number of plications in the fold and sinus,† but otherwise closely resemble the Gotland form.

As to the derivation of *P. dentata*, the same argument that derives the closely related *P. biforata* from a primitive uniplicate stock holds in the present case. *P. dentata* was derived from such a primitive stock, probably at about the same time with *P. biforata*, and by the same process of acceleration of the point of bifurcation of the primary plication of the sinus. The transitional stages are to be sought in Russian deposits, since *dentata* is absent from the American Ordovician.

In Niagara time the species spread westward into Gotland, and from there into England and Ireland and the Gulf of St.

* Cin. Quar. Jour. Sci., vol. ii, 1875, p. 27.

† On the Anticosti form see Shaler, Bull. Mus. Comp. Zoöl., iv, 1865, p. 67, and Brachiopoda of the Ohio Valley, p. 44. This is the form to which he gave the name *regularis*. On the Kentucky form see Nettleroth, Kentucky Fossil Shells, 1889, p. 35, pl. 29, figs. 18, 19.

Lawrence.* By another route the form reached the Mississippi area of this country, where it is very poorly represented.†

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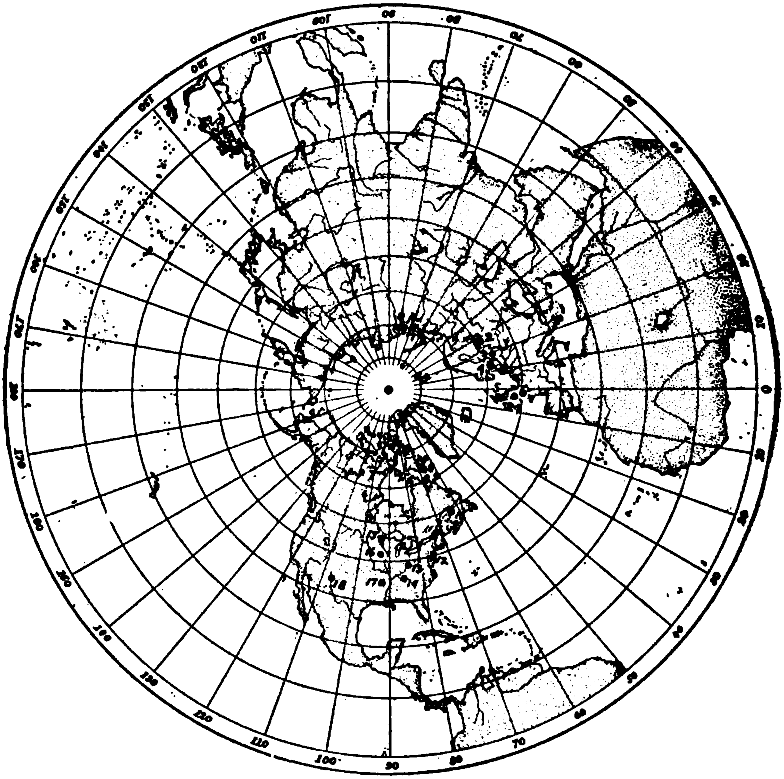

FIG. 24.—Map showing distribution of *Platystrophia*. 1, Khabarova; 2, Russian Province; 3, Island of Gotland; 4, West Gotland; 5, Scotland; 6, Wales; 7, Ireland; 8, Baffinland; 9, Akpatok Island; 10, Anticosti; 11, New York—Canadian Ordovician province; 12, New Jersey; 13, Cincinnati region; 14, Tennessee region; 15, Minnesota; 16, Missouri; 17, Arkansas; 18, New Mexico. Stereographic projection, after Penfield.

* *Platystrophia* occurs in the Wisby (Unter-Mergel) formation of Gotland (Schmidt), associated with *Bilobites biloba*, *Rhipidomella hybrida*, *Strophomena depressa*, *Rhynchotreta cuneata*, etc., and in the lower part of the Middle Gotland formation. These beds are equivalent, according to Lindström, to the Wenlock of Britain (Niagara of this country). See Schmidt, Archiv. Liv.-, Ehst.- und Kurlands, ser. i, ii, 2, 1854, pp. 426, 453, 454; and Lindström, Of. Sven. Vet. Akad., xvii, 1860, p. 381; Neues Jahrbuch f. Min. Geol. u. Pal., 1888, i, pp. 147–164.

† An occasional individual from the Clinton of Rochester, N. Y., presents somewhat the appearance of *P. dentata*, but with a larger number of plications and a shallower sinus. They are probably the young of *P. biforata*.

From the Niagara of Osgood, Indiana, I have a single specimen (Schuchert collection) which is identical with the neanic stage of the Gòtland form. It may be an immature individual.

The presence of the Gotland type of *Platystrophia dentata* in the Niagara of the Ohio valley is of interest in connection with the strong resemblance of the Silurian faunas of the Chicago area to the Gotland faunas, pointed out by Weller,* and indicates a westward movement of the latter through the Hudson Bay route during Silurian time. In this connection it is also to be noted that the *Platystrophia* of the Wenlock of England and Ireland, judging from Davidson's figures,† is of the same type as that of Anticosti, that is, larger and less angular than the Gotland form. The relations of these several geological provinces will be readily understood by reference to the map, fig. 24. The extremely small size and simplicity of the Gotland and Osgood specimens is of special interest. Some of the former have in the adult but four plications on the lateral slope, and are therefore strictly comparable to the neanic stage of the normal Ordovician types. Such a complete return to the primitive type is rarely seen (see No. 16, and xix, fig. 27).

Platystrophia dentata is fully entitled to rank as a species, although in the Ordovician deposits of Russia, according to de Verneuil, it is connected by intermediate forms with *P. biforata.* Its distinctness and wide distribution during the Silurian are facts of greater import than the presence of such linking forms in the Ordovician.‡

Abnormal and Pathologic Types.—No truly pathologic shells of this genus have come to the writer's notice, with the exception of a series of specimens submitted by Mr. Charles Schuchert of the U. S. National Museum. These shells, two of which are shown in fig. 25, are from the Richmond beds of Waynesville, O. They are all small, frequently distorted, as in fig. 25, *a*; and show a pronounced tendency to obsolescence of the plications at varying stages of growth. In fig. 25, *a*, this tendency does not manifest itself till late in the ontogeny, after the formation of a very conspicuous growth varix. In fig. 25, *b*, the plications become obsolete a short distance from the apex of the beak, and farther forward regain nearly their normal strength.

* Jour. Geol., vi, 1898, p. 697. Cf. Dana, Man. Geol., 4th ed., 1894, p. 536. De Lapparent, Traité Géol., 1900, pp. 809, 823 (Maps).

† Silurian Brachiopoda, 1869, pl. xxxviii, figs. 11, 20, 24.

‡ It may be well when these early linking forms of *P. biforata* and *P. dentata* are more carefully studied to distinguish them by a varietal or subspecific name, as I have done in the case of *P. laticosta*.

It is rather difficult to assign these shells to any one of the common types of *Platystrophia.* From their occurrence and association, as well as from the aspect of the early ontogenetic stages, it seems almost certain that they are pathologic individuals of the *acutilirata* group. The individual shown in fig. 25, *a*, certainly presents every appearance of a normal *acutilirata*, up to the formation of the first strong growth varix. When normal growth was interrupted the shell reverted to a simpler, more primitive type, so that the later stages are strongly suggestive of *P. lynx.* The obsolescence of plications which, we have seen, characterizes gerontic stages only of normal shells, here affects ephebic stages as well, and to a profound degree. In both cases it is the direct result of the failing vitality of the organism. In the former case, however, the failure is a normal phase of ontogeny; in the latter, it is due to the stress of an adverse environment, to which the organisms attempted, with varying success, to adjust themselves.*

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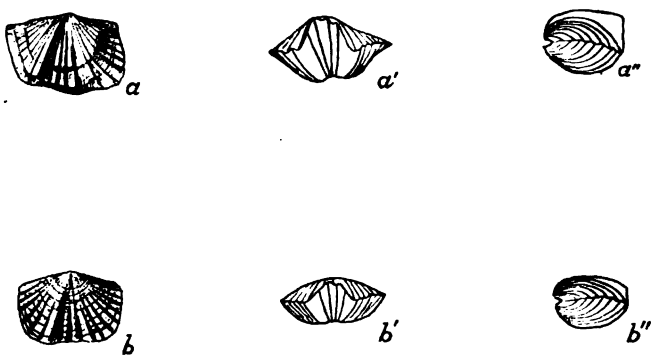

Fig. 25.—Pathologic individuals of the *acutilirata* type from Waynesville, O. In *a* the shell is greatly distorted owing to irregularity of growth, and the plications are obsolescent near the lateral margins. In *b* the plications become nearly obsolete a short distance from the beak and then continue with nearly normal strength to the margins. Schuchert collection.

* This subject has been ably discussed by Hyatt. Genesis of the Tertiary species of Planorbis at Steinheim, Anniversary Mem. Bos. Soc. Nat. Hist., 1880, p. 15.

[To be continued.]

ART. II. — *On Ruling Concave Gratings;* by WILLIAM ROLLINS.

LYMAN has shown that the Rowland concave grating gives false spectral lines so sharp and clear "there is probability and some evidence" they have been mistaken for real lines. As the concave grating is a beautifully direct method of obtaining spectra, it seemed desirable to consider the causes of its defects and try to remedy them, rather than to return to flat gratings with their lens complications.

Briefly stated, the process of preparing a concave grating is to grind and polish the surface of the metal block to the proper curvature, afterward mounting it on a carriage moving on straight ways by means of the long nut of the precision

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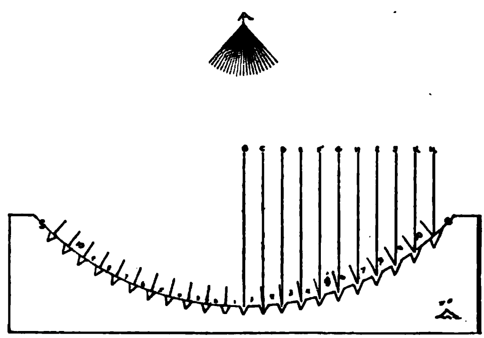
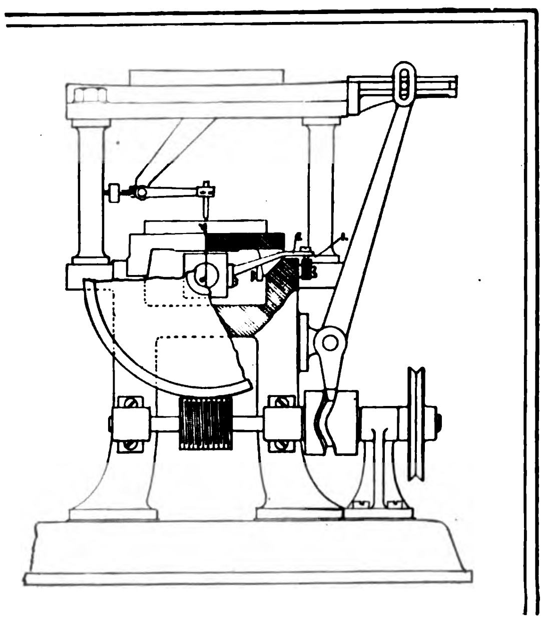


screw, which carries the metal blank under the diamond as the screw turns. This method, while well adapted to making flat gratings, does not yield concave gratings in which the grooves cut by the diamond are the same distance apart, and cannot produce them with sides having equal faces or forming the same angles with the surface of the metal in different parts of the grating. The shorter the focus of the grating the more marked are these defects.

Figure 1 is a diagram intended to show them exaggerated. The lines B to K represent equal movements of the grating under the diamond point, as produced by the uniform motion of the screw. If the grating were flat the resulting cuts would be equally spaced, while the angles formed with the surface by the sides of the cuts would be alike in all parts of the grating. In the case of the curved grating the distance between the cuts, measured on the surface of the grating, increases from the

center toward each end, as may be seen at 1 to 10 on the right of the figure, while the angles formed with the surface by the sides of the cuts vary constantly; moreover, the width of the faces of the same cut is different. The first defect might be corrected by a compensating device attached to the spacing screw nut, but the second and third cannot be with the present methods of ruling. If the block to be ruled were fixed, the diamond point pivoted at a center, A, corresponding with the center of curvature of the grating mechanism, could be arranged to move the diamond through equal arcs, producing equal

2



spacing and lines with equal faces and equal angles with the surface, as shown on the left of the figure at 1 to 10. In the case of seven meter gratings the arm would be so long that vibration might be difficult to deal with. Instead of moving the diamond through an arc, the carriage moved by the screw might be pivoted at the center of curvature of the grating and swing through an arc on curved ways; the nut not being rigidly attached to the carriage, but imparting motion to it by an arm. On account of the vibration factor a different method has been chosen for illustration. The usual screw is used, with a long nut to impart motion to the carriage, which moves on curved ways, instead of on flat ones, as at present in all ruling

machines. The size of the curved ways is such that the blank moves under the diamond in an arc whose radius is the same as the curvature of the grating. This causes the cuts made by the diamond to all have the same angle with the surface and their sides to be of equal widths. It does not make the spacing equal, but this may be compensated for as already mentioned. The plan of compensation shown in figure 2 was

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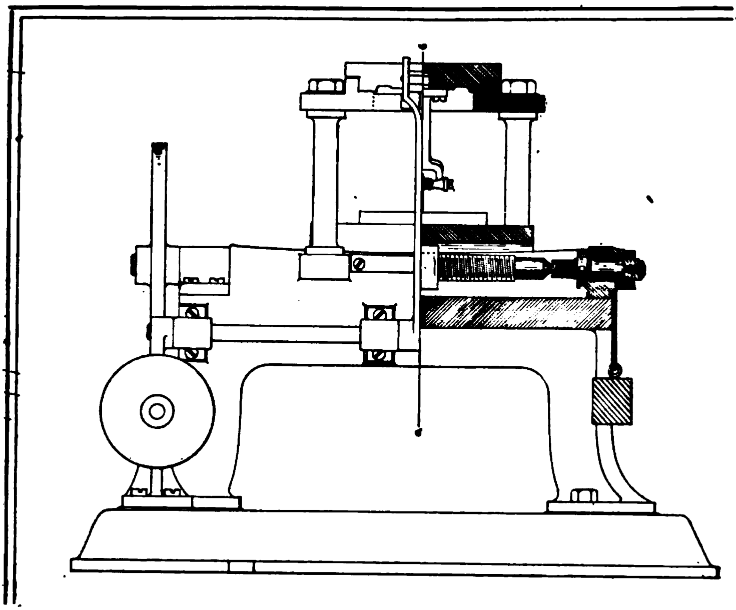

devised by Mr. William Gaertner, to whom and to Captain Khotinsky I am indebted for working out the drawings shown in figures 2, 3, 4. The nut in this machine is not rigidly attached to the carriage carrying the grating, but motion is imparted to the carriage by means of a projecting arm, which, sliding on a curved way, allows the nut to turn sufficiently to equalize the spacing.

In figure 5 another way of carrying out the principle is illustrated diagrammatically, the curvature of the grating being made very short to show the idea more clearly. The block, BK, to be ruled is mounted on the carriage, C, which moves in an arc on curved ways, motion being imparted to it from the long nut, SN, by a band of thin, tempered steel attached at N′ and N‴. As the nut SN is moved to the left, in the direction of the arrow 1, the carriage, C, turns in the direc-

tion of the arrow 2, as shown by the dotted lines, bringing different parts of the block, BK, under the ruling diamond, D. This arrangement requires no compensating device, except for the periodic errors of the screw, which may be present in any form of ruling machine. In the case of a concave spherical grating this mechanism would make the lines with equal spaces, while if a section were cut through the grating, as in figure 1, the grooves would all have the same angles with the surface. It will always be mechanically impractical to make a

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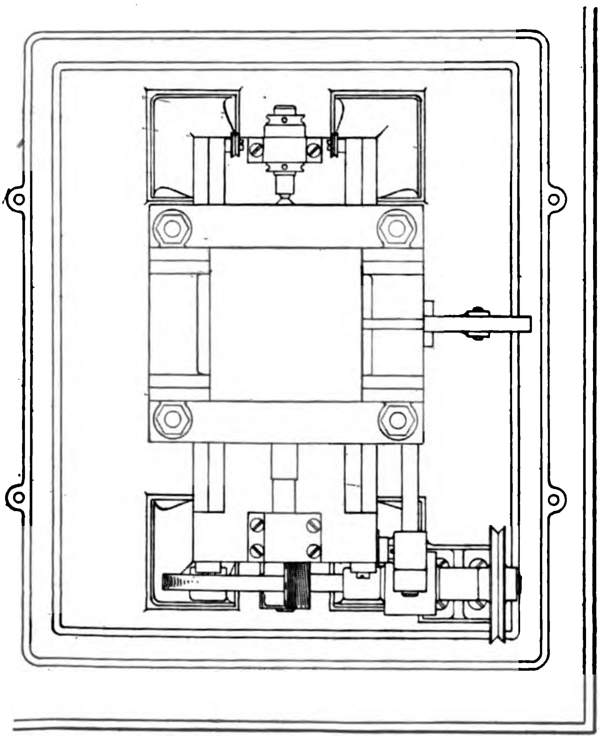

machine in which this is true through the whole ruled surface of a concave spherical grating, but if the surface of the grating is concave cylindrical then the plan shown in figure 5 is capable of overcoming all the defects mentioned in the first part of the paper. Another difficulty with the present methods of ruling concave spherical gratings remains to be considered, namely, the diamond must rule both up and down hill. No diamond does this well, consequently the forward and back

motion of the diamond should be controlled by a carriage moving on curved ways, that the long axis of the diamond may always preserve the same angle with the surface of the grating.

For the idea of applying the curved ways to the movement of

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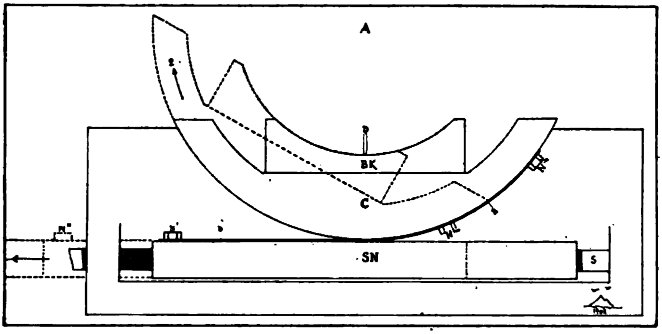

the diamond I am indebted to Captain Khotinsky, whom I engaged to make the drawings for a ruling machine which was to embody the ideas which had occurred to me during a study of my Rowland grating.

Boston, Mass.

ART. III. — *The Variation of Potential along a Wire Transmitting Electric Waves;* by C. A. CHANT.

I. *Introductory.*

HERTZ* was the first to explore a wire along which electric undulations were passing. His oscillator consisted of two sheet-brass plates 40^{cms} square, connected by a copper wire 60^{cms} long, in the middle of which was a spark-gap. Opposite and parallel to *one* plate was placed another of equal size, from which was led off a copper wire, the first meter of which was curved and the rest of it straight. As a detector he used his circular resonator, 70^{cms} in diameter. The nodes were well marked in two wires, the length of the straight portions of which were 5·5^{m} and 8^{m}, respectively. The half-wave-length was determined to be 2·8^{m}.

These experiments were repeated and extended by Sarasin and de la Rive,† who somewhat increased the effect by using two wires led off from two plates placed opposite the oscillator plates, the resonator being held between them. These experimenters showed very clearly that the apparent wave-length measured along the wire was dependent purely on the size of the resonator, the wave-length being equal to eight times the diameter of the resonator.

Somewhat similar results were obtained by Waitz,‡ who used a circular resonator, to which were attached two wires, one joined near each terminal knob, and led off either parallel to each other or in opposite directions. In the former case, by sliding along a bridge laid across the wires, the sparks between the resonator knobs passed through maximum and minimum intensities; in the latter case, by hanging capacities on the wires and sliding them along, the sparks varied similarly. He worked with plate oscillators of two sizes, as well as cylindrical and spherical ones. He found that his minima depended entirely on the dimensions of his circular resonator.

The conclusion naturally drawn by Sarasin and de la Rive and Waitz from their experiments was that the oscillator emitted waves of various lengths, extending over several octaves; but this hypothesis has been shown to be improbable, a more satisfactory explanation being based on the fact that the oscillations of the oscillator are very rapidly damped, while those of the resonator are very persistent.§

* H. Hertz, Wied. Ann., xxxiv, p. 551, 1888. Electric Waves, p. 106.

† E. Sarasin and L. de la Rive, Archives des Sciences Physiques et Naturelles. Genève, xxiii, p. 113, 1890.

‡ K. Waitz, Wied. Ann., xli, p. 435, 1890.

§ See Poincaré, Les Oscillations Électriques, Art. 55 and fol. J. J. Thomson, Recent Researches, p. 340.

In Lecher's* experiments the exciter consisted of two sheet-metal plates, 40^{cms} square, joined by a bent wire 2^{m} long, with a spark-gap in the middle of it. Opposite each plate and parallel to it was another of the same size, from which ran long, straight, parallel wires. On the farther ends of these was laid a vacuum tube, and across the wires at different points were laid metallic bridges. When these were properly placed, namely, at the potential nodes, the tube at the ends lighted up. The wave-lengths he obtained, however, were not those proper to the exciter, but those of that part of the wire-system on that side of the first bridge next the plates, which was in resonance with the rest of the wire-system.

In Cohn and Heerwagen's† experiments with Lecher's method a condenser was added to the ends of the wires.

Blondlot‡ also experimented with parallel wires, but used an oscillator of quite different construction. In Lecher's arrangement the capacity is large compared to the self-induction; in Blondlot's the reverse is the case. The latter has the advantage that the damping is much diminished.

These "wire-waves" have been the subject of numerous investigations, a notable one being that by Drude.§ He found that the oscillator must be considered as composed of the Blondlot semicircular primary exciter, together with that portion of the secondary wire-system as far as the first bridge; and that when the bridges are properly placed there is resonance between this oscillator and the rest of the system. Very convenient forms of this apparatus are given by Coolidge‖ and Hormell.¶

Donle,** who used chiefly the Blondlot oscillator, joined the ends of the parallel wires with a glow-lamp. His aim was to diminish the wave-lengths, which he reduced to 130^{cms}. Coolidge's smallest wave-length was 12^{cms}.

In Rubens's experiments the exciter was of the Hertzian form, with plates 40^{cms} square. The two opposing parallel plates were but 10^{cms} square, though the smaller plates are not quite as efficient as those of equal size.†† From these smaller plates the parallel wires went out,—in this instance to a distance of 570^{cms},—and were explored by a bolometric method. Rubens‡‡ found that the oscillations along the wires were not

* E. Lecher, Wied. Ann., xli, p. 850, 1890.
† Cohn and Heerwagen, Wied. Ann., xliii, p. 343, 1891.
‡ R. Blondlot, Comptes Rendus, cxiii, p. 628, 1891.
§ P. Drude, Eine bequeme Methode zur Demonstration des electrischen Brechungsexponenten von Flüssigkeiten. Wied. Ann., lv, p. 633, 1895.
‖ W. D. Coolidge, Wied. Ann., lxvii, p. 578, 1899.
¶ W. G. Hormell, this Journal, xii, p. 433, 1901.
** W. Donle, Wied. Ann., liii, p. 178, 1894.
†† Drude, Physik des Aethers, p. 446.
‡‡ H. Rubens, Wied. Ann., xlii, p. 154, 1890.

the same as those of the oscillator; in other words, the oscillations were not forced along the wires, but were those natural to them.

These experiments were verified by Rutherford,* who substituted a magnetic detector for the bolometer, and found it equally sensitive.

In all these experiments it will be observed that the wave-lengths determined along the wires are not those proper to the oscillator, but are either due to the detector used or to the wires vibrating naturally.

In Birkeland's† and Jones's‡ researches the reverse seemed to be the case. The wire-systems were both similar to that of Sarasin and de la Rive, but the means of exploration were different. Birkeland examined the potential at various points of his wire, which was 30^{m} long, by measuring the length of the spark which leaped from it to an earth connection, the existence of the spark being indicated by a telephone receiver held to the ear. He obtained minimum points which varied as the period of the oscillator was changed, thus indicating that the measured wave-length depended on its period. These minima were unequally spaced, which irregularity was attributed to the damping of the waves and the loss on reflection at the ends of the wires; but the explanation does not seem entirely satisfactory.§

Jones used a thermal junction inserted at different points of his wire, which was 130^{m} in length, the effect being indicated by a low-resistance galvanometer in circuit with it. The oscillator was of the usual type, with plates 40^{cms} square, but the length of the connection between the plates is not given. Several well-defined maxima and minima were observed, and the wave-length was determined to be approximately $4{\cdot}3^{m}$. It is interesting to read that "several curious results were recorded for which no explanations were forthcoming."‖

It may be worth while to recall how the wave-length of Hertz's plate oscillator was determined. He obtained it with the aid of his circular resonator, but, as has been already remarked, the wave-length thus found is always eight times the diameter of the resonator. If, then, we could know when the resonator was exactly in unison with the oscillator, the wave-length could be deduced with considerable accuracy. But this is not at all possible; the resonance is far from being sharply defined. Indeed, Hertz says that the same resonator, of diameter 70^{cms}, was in resonance with three different oscillators. The first consisted of two spheres of diameter 30^{cms}, connected

* E. Rutherford, Phil. Trans. A, 1897, clxxxi, p. 1.
† Kr. Birkeland, Wied. Ann., xlvii, p. 583, 1892.
‡ D. E. Jones, Brit. Assoc. Report, 1891, pp. 561–2.
§ See Poincaré, l. c., p. 176.
‖ Nature, xliv, p. 454, 1891.

by a wire 70^{cms} long, with a spark-gap in the middle; the second, of two plates 40^{cms} square, joined by a wire 70^{cms} long with a spark-gap as before; the third had plates of the same size, but the wire was 60^{cms} long.*

Thus the wave-length emitted by each of these was taken to be the same, namely, 560^{cms}. Now the period and wave-length of the first oscillator have been found theoretically. Hertz† calculates the period to be 1·26 hundred-millionths of a second and the wave-length to be $4·6^m$, while Drude‡ makes the latter $4·8^m$. Both values differ considerably from that obtained by resonance. Again, the second and third oscillators differ considerably in period, though that of the second was found to be the same as that of the first. (See below.) We must conclude that the wave-length $5·6^m$ is not a very close approximation.

In the experiments to be described presently it will be seen that oscillators of the same type may differ decidedly in their behavior; that some seem able to force their vibrations upon a wire, while others cannot. The wave-length of an oscillator, the same as the third of the three just described, was concluded to be 5·88 meters.

II. *Experimental Arrangement.*

While engaged during the session 1900–1, in the Jefferson Physical Laboratory of Harvard University, on another investigation§ in which the magnetic detector was used, the fact that an electrical disturbance about a wire parallel to the wings of the detector exerted a strong action on the detector, was continuously and painfully evident. Indeed, the effect arising from the connecting wires at first entirely masked the true radiation from the oscillator.

This suggested the possibility of conveniently exploring the field along a wire by shortening the wings of the detector and then placing it close to the wire at various points in its length. The experiment was tried, but the demagnetization of the detector was small. However, on removing one wing and placing the other near the wire the effect was much greater and easily measurable.

But the action with one wing is not at all the same as with two. When the detector with two wings is placed along the wire, the surging in its helix and the consequent demagnetization is greatest at points where the current oscillation is great-

* Hertz, Electric Waves, Art. V, p. 81–2; Art. VI, p. 96–7; Art. VII, pp. 108 and 113.

† Hertz, l. c., p. 51 and p. 270 (note 6).

‡ Drude, Physik des Aethers, p. 397. See also J. J. Thomson, l. c., Arts. 289 and fol.

§ C. A. Chant, An Experimental Investigation into the "Skin"-effect in Electrical Oscillators, this Journal, xiii, p. 1, 1902. Phil. Mag., VI, vol. iii, p. 425, 1902.

est, i. e., at a current loop; the effect is least at a current node. With a single wing these results are exactly reversed,—the effect is greatest at a current node, which is, of course, a potential loop. This can be explained in the following way: The little wing and the portion of the wire just beside it act as a miniature condenser, and when there is a maximum variation of potential in the element of wire there will also be a maximum variation in the detector wing, which will cause currents to surge back and forth in the helix and so to demagnetize the iron core. At a current loop (or potential node), the variation in potential is a minimum, and so the detector when placed there will show minimum demagnetization. Indeed the indications of the magnetic detector should be precisely similar to those of the bolometer as used by Rubens.

An attempt was then made to force standing waves in a wire, and preliminary experiments seemed to show the possibility of determining the wave-lengths of oscillators in this way. Some measurements were made then, which, since returning to Toronto, have been considerably extended.

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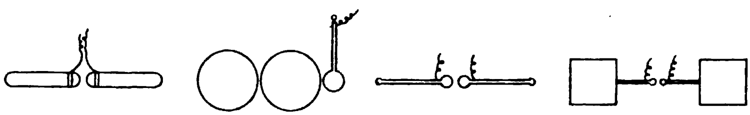


a *b* *c* *d*

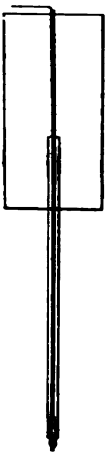
The oscillators were of four kinds, illustrated in fig. 1. The cylinders of (*a*) were $2{\cdot}5^{\mathrm{cms}}$ in diameter and $12{\cdot}5^{\mathrm{cms}}$ long, with hemispherical ends; the spheres of (*b*) were of two sizes, namely, with diameters of 10^{cms} and 30^{cms}, respectively; the larger spherical ends of (*c*) were 19^{mm}, the smaller 6^{mm}, and the straight portion $4{\cdot}2^{\mathrm{mm}}$, in diameter, while the length over all was $12{\cdot}5^{\mathrm{cms}}$; in (*d*) is shown the ordinary Hertzian plate oscillator.

The sparks were produced by an induction coil capable of giving sparks $12{\cdot}5^{\mathrm{cm}}$ long, and fed by five accumulators in series.

The interrupter was similar to that used in the other investigation. It consisted in a platinum-tipped rod, which, by means of a motor, was alternately plunged into and withdrawn from mercury, the surface of which was kept clean by a stream of water continually flowing over it. In series with this were a pendulum interrupter and a contact key. This key was depressed during any desired number of vibrations of the pendulum,—usually five swings,—during which time the coil was interrupted approximately sixty times. This number, of course, varied somewhat with the speed of the motor, but it did not change much during any series of readings.

The magnetic detector was the same as that used in the other research. It had twenty pieces of iron, $0{\cdot}014^{cm}$ in diameter and 1^{cm} long, insulated from each other by paraffine, and wound over with ninety turns of fine insulated wire. It was mounted in the end of a glass tube, and all held on a small sheet of hard rubber by means of wax. It is shown one-half of natural size in fig. 2.

2



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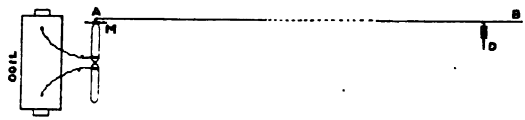

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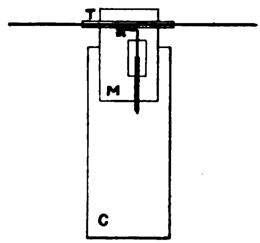


The magnetometer and telescope, as well as the method of placing the detector behind the magnetometer, were as described in the former paper.

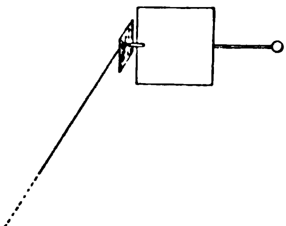
The manner of producing the oscillations along the wires is shown (for the cylinders) in fig. 3. AB is a long straight wire ($0{\cdot}7^{mm}$ in diam.), ending at A in a small knob 6^{mm} in diameter, which was separated from an end of one of the cylinders by a piece of mica, M, usually $0{\cdot}15^{mm}$ thick. By this means the surgings on the cylinders were impressed upon the wire, which was explored by placing the little detector near it at different points in its length.

Since the magnitude of the effect depends on the distance the detector wing is held from the long wire, it was necessary to regulate this accurately. To do so a small glass tube, about 4^{cms} long, T, fig. 4, with bore just great enough to allow it to slide over the wire, was taken, and to the outside of this was fastened a bit of finely-drawn tubing, *m*, into which the wing fitted snugly. In all the experiments the wing was 1^{cm} long.

The glass tube was attached to a piece of hard rubber (or mica), M, which, again, was cemented to the top, C, of a carriage which moved along beside the wire.

Thus, to examine any portion of the wire, the carriage was moved along to the required place, the distance of which from the end of the wire was measured by a scale on the ways on which the carriage moved. The detector was magnetized, then placed in its pocket beside the glass tube, and sparks made to pass at the oscillator for a certain length of time. The detector was then removed and examined by the magnetometer. This process was systematically carried out, beginning at the end of the wire and advancing by equal spaces.

5



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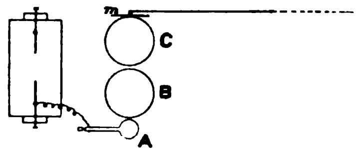

For the linear oscillator, shown in fig. 1, *c*, the arrangement was precisely the same as for the cylinders. For the Hertzian oscillators, fig. 1, *d*, a rounded end was given to one of the plates by taking a piece of brass rod 6^{mm} in diameter and about 2^{cms} long, rounding the ends, and then making a slit in one end, which allowed it to be slipped over the plate. This is shown in fig. 5.

The arrangement for the spherical doublet is shown in fig. 6. When the coil was in action sparks passed between A and B and B and C, and the oscillations on the sphere C were transmitted to the wire across the mica plate, *m*.

The wires used were quite short, ranging from 1 meter to 8·6 meters in length.

III. *Results of Experiments.*

It will be convenient to divide the results into two parts: A, those obtained with the oscillators *a*, *b*, *c*, of fig. 1; and B, those with the Hertzian oscillators.

A. *Cylindrical Oscillator (fig. 1, a).*

In fig. 7, *a*, *b*, *c*, are shown curves obtained with the cylindrical oscillator, which was made of sheet platinum on a wooden form with well-shaped hemispherical ends. Here, as always, the greatest variation in potential was at the end of the wire. It gradually fell until a minimum was reached at approximately 20^{cms} from the end, and after another rise it dropped again to a minimum at approximately 60^{cms}. Each of the last two curves gives a half-wave-length of 40^{cms}, the first one 38^{cms}, or a mean wave-length for the oscillator of approximately 79^{cms}.

In every instance the actual readings are shown.

Linear Oscillator (fig. 1, *c*).—Curves obtained with this oscillator are shown in fig. 7, *d*, *e*. Curve (*d*) is the mean of

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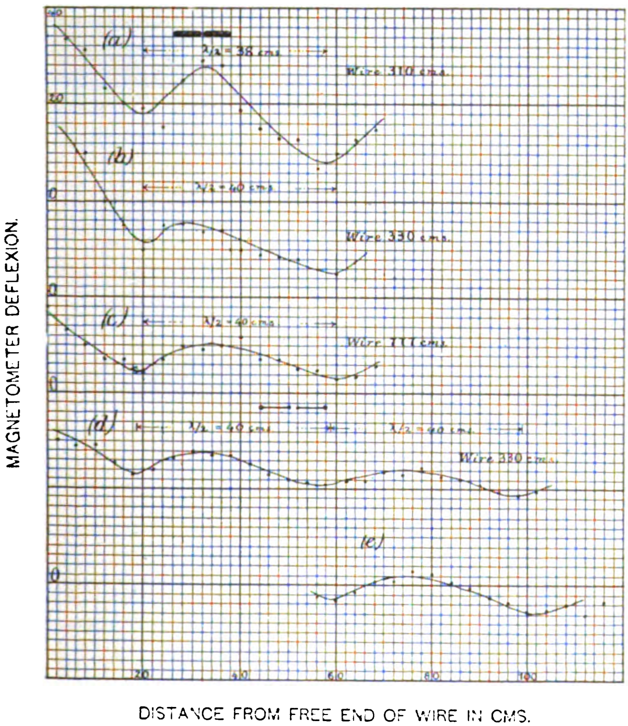


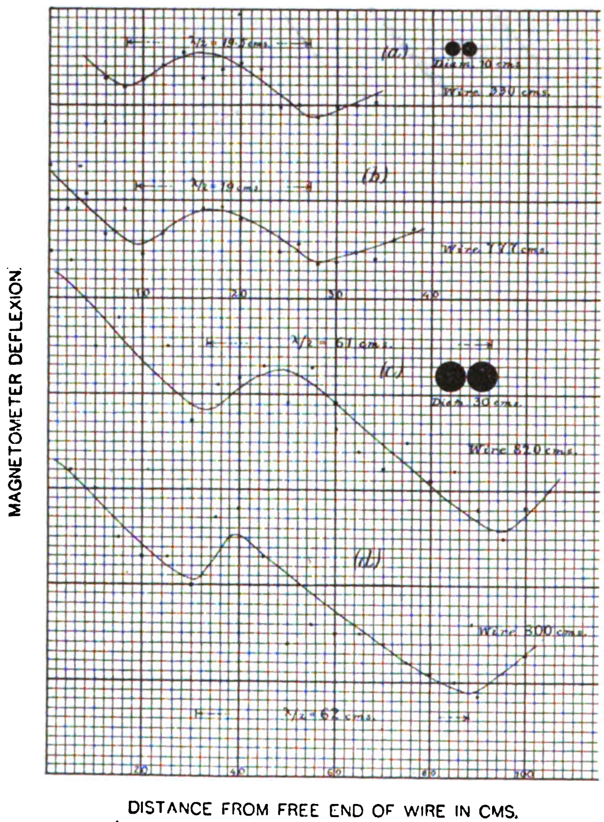
two sets of readings with five swings of the pendulum. The mean of five sets, each of two swings, gave the same minima, though the curve was not so good. Curve (*e*) is a repetition of the second portion of the readings; it is the mean of two sets of five swings each.

Here three minima are easily seen at 19, 59, and 99$^{\text{cms}}$, respectively, from the end; and the wave-length is thus approximately 80$^{\text{cms}}$.

Spherical Doublet (fig. 1, *b*).—Curves for this oscillator are given in fig. 8. It was much more difficult to get consistent series of readings with it. Curves (*a*) and (*b*) are for the 10$^{\text{cm}}$ spheres. The half-wave-lengths deduced are, respectively, 19 and 19·5$^{\text{cms}}$, with a mean wave-length of 38·5$^{\text{cms}}$. Curves (*c*) and (*d*) are for the 30$^{\text{cm}}$ spheres. The half-wave-lengths from these are 61 and 62$^{\text{cms}}$, respectively, with a mean wave-length of 123$^{\text{cms}}$.

These curves are not as smooth as the former ones, but are perhaps as good as one should expect with so dead-beat an oscillator.

8



From the results with the 10^{cm} spheres the ratio of wave-length to diameter is 3·85, while with the 30^{cm} spheres this ratio is 4·1.* The theoretical value given by J. J. Thomson† is 3·6.

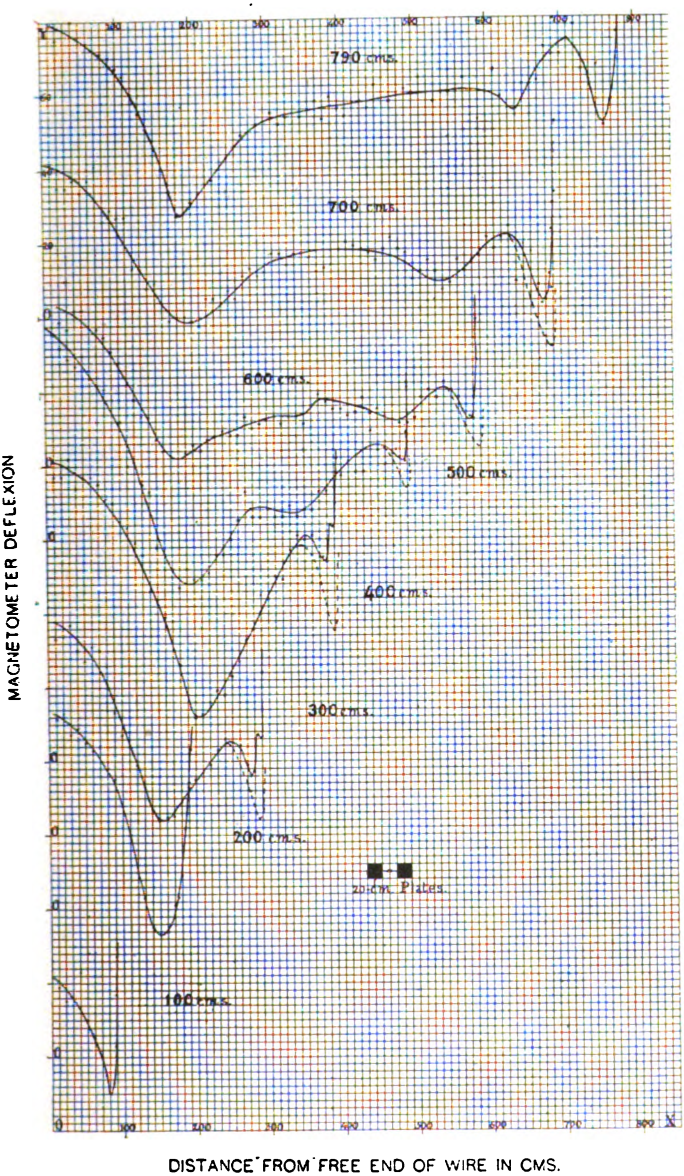
Further exploration of the wire revealed no more minima.

* It may be interesting to compare values of this ratio obtained by other experimenters. Some are given in the following table, taken from a paper by Hull in the Physical Review, vol. v, p. 231, 1897:

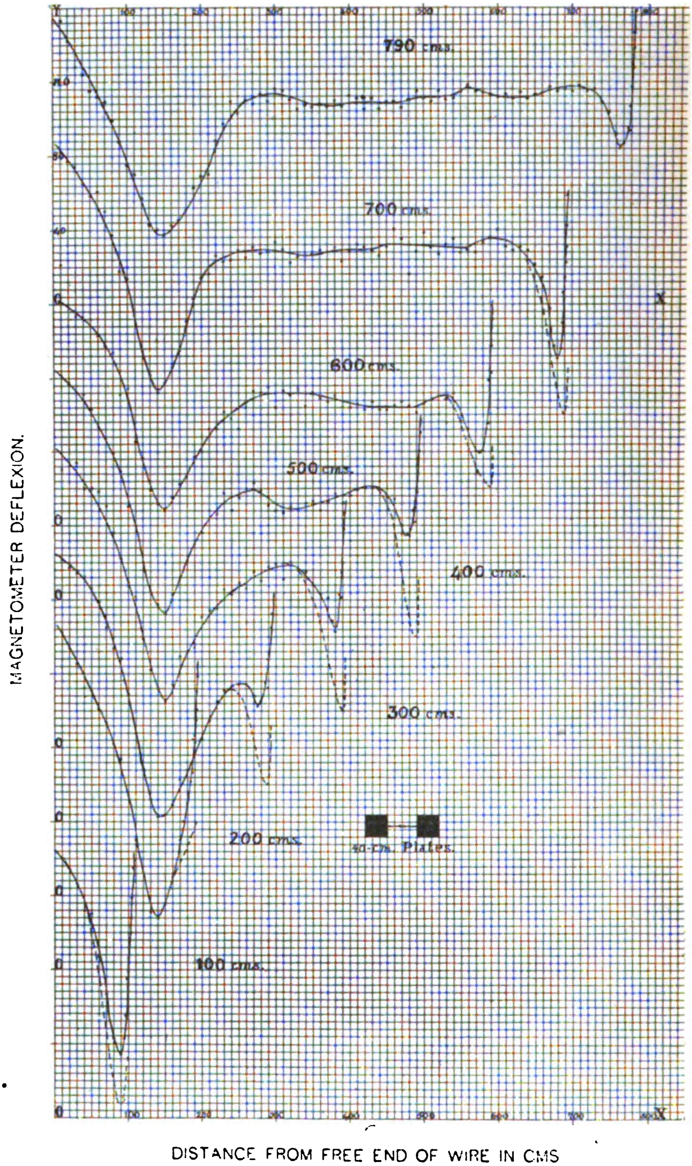
Diam. in mm.	λ in mm.	λ/Diam.	Experimenter.
80	200	2·50	Righi
37·5	106	2·83	"
8	26	3·25	"
7·8	18·4	2·36	Bose
19·3	91	4·71	Hull
9·3	43	4·62	"
7·9	40	5·18	"

† J. J. Thomson, l. c., p. 370.

9


790 cms.
700 cms.
600 cms.
500 cms.
400 cms.
300 cms.
200 cms.
100 cms.
20 cm. Plates.
MAGNETOMETER DEFLEXION
DISTANCE FROM FREE END OF WIRE IN CMS.

10



Y
790 cms.
700 cms.
600 cms.
500 cms.
400 cms.
300 cms.
200 cms.
100 cms.
40-cm. Plates
X
MAGNETOMETER DEFLEXION.
DISTANCE FROM FREE END OF WIRE IN CMS

Wire 500cms.	Wire 400cms.	Wire 300cms.	Wire 200cms.	Wire 100cms.
	197..			
	197..			
	199..			
	203..			
	148..205..			
	152..197..			
	150..200..			
	..203..			
	152..			
207..350..490	202..390	154..290	150	85
195..347..490	210..390	155..290	148	85
195..365..490	206..390	152..		
188 ?..				
195 ?..				
	205..			
	208..			
	207..			
	200..			
	202·6			
	124..196..260..			
	140..200..262..			
	142..215..			
	125..207..271..			
	127..197..272..			
	122..200..260..			
	133..			
	132..			
	132..			
	131..			
152..355 ?..490	149..387	143..290	140	82·5
150..355 ..490	147..387	150..290	138	82·
150..335 ?..490	149..	150..		
154..				
	170..			
	177..			

B. *The Hertzian Oscillators.*

With the Hertzian oscillators the results were quite different from those just given, and indeed they differed considerably among themselves.

The first oscillator tried had sheet-zinc plates 40^{cms} square, with the straight wire between them 60^{cms} long; and the wire transmitting the waves was 860^{cms} long. One minimum was very well marked, but there were no more clear ones. Then a

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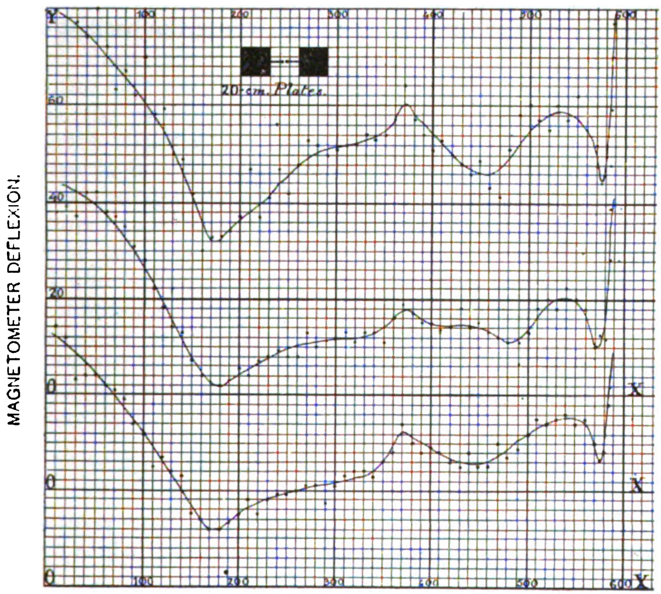


DISTANCE FROM FREE END OF WIRE IN CMS.

second oscillator, with 20^{cm} plates, and otherwise of just half the size of the former was tried, but the minimum, instead of being half the distance from the end, was much farther from it. This led to the making of additional oscillators, with plates 10, 15, 25, 30, 35, 50^{cms} square, respectively, and with the wires between of proportional length. The spark-knobs were 19^{mm} in diameter, the same knobs being used with all the oscillators.

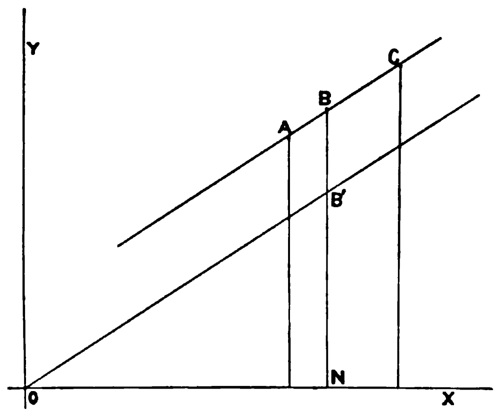
Using these oscillators, readings were taken with wires from 100 to 860^{cms} long; and the results obtained are exhibited in the accompanying table and curves. In the table, the positions of the minima are given by stating their distances in centimeters from the free end of the wire. There was always one more marked than the others, and this one, indicated in the

table by more prominent type, will be referred to as the *chief* minimum.

In fig. 9 are shown readings and curves obtained with the 20^{cm} oscillator with various lengths of wire, and in fig. 10 are similar readings with the oscillator of double the size, i. e., with 40^{cm} plates; while in fig. 11 is shown a series of three successive curves given by the 20^{cm} oscillator with the same length of wire. These illustrate the method moderately well.

Remarks on the Table and the Curves.—A glance at the table will show that the oscillators used can be divided into two distinct groups, the first including the four smaller ones, and the second the three larger ones, while the oscillator with

12



30^{cm} plates lies between the two groups. The results with each group are consistent among themselves, while the 30^{cm} oscillator behaved in a very irregular manner.

For the first group (the smaller ones), the positions of the minima for any particular length of wire are independent of the size of the oscillator, i. e., they depend only on the wire's length. In this case the oscillator does not force its period on the wire.

In the second group, on the other hand, the positions of the minima depend only on the size of the oscillator, not at all on the length of the wire.

The conclusion seems natural that, in this latter case, the distance of the minimum from the free end is one-quarter of the wave-length of the oscillating system. The values of this quarter-wave-length deduced from the table are:

For 35^{cm} oscillator	....	$132{\cdot}7^{cms}$	(mean of	11 results).
" 40 "	....	147·1	"	21 "
" 50 "	....	·171·5	"	6 "

Now it is possible that the proximity of the wire to the oscillator may have the effect of virtually increasing the size of the oscillator, and if such is the case all the quarter-wave-lengths so determined are too great. According to Poincaré's* deduction from the homogeneity of the fundamental equations, the wave-length of an oscillator or resonator varies directly with its linear dimensions. In fig. 12 the points A, B, C have abscissæ proportional to the dimensions of the three larger oscillators and ordinates proportional to the quarter-wave-lengths given above. It is seen that they lie very approximately on a straight line, but this line does not pass through the origin. Let us now draw a line parallel to it and passing through the origin. The ordinate B′N of this line, corresponding to the 40^{cm} oscillator, has a length of approximately 103^{cms}. Thus if the principle of direct proportionality, stated by Poincaré, held without limit to its application, the arrangement of the wire as in the experiments should be equivalent to adding 44^{cms} to the quarter-wave-length of each of the three larger oscillators. On the other hand, the fact that varying the length of the wire from 3^{m} to $8{\cdot}6^{m}$ had no effect on the position of the minimum, seems to show that the wire did not act in the manner referred to. In other words, the quarter-wave-lengths given are proper to the oscillators.

Experiments with the first and second Hertzian oscillators, referred to above, gave the following values for the quarter-wave-length:

For 40^{cm} plates,	straight connection	70^{cms}	$154{\cdot}4^{cms}$
30 spheres,	" "	"	$153{\cdot}9$

These are practically identical.

For all wires of three meters and upwards in length there is a well-defined minimum between 10 and 15^{cms} from the end next the oscillator. In figs. 9, 10 is shown a portion of each curve near the oscillator in continuous line, and also in broken line. In this neighborhood the oscillator exerted a strong action directly on the detector. In order to allow for this, readings were first taken as usual (shown by continuous line); then the wire was removed and readings taken at exactly the same points. These latter were then subtracted from the former, and the broken line shows the result. Here it is assumed that the action of the oscillator and of the wire singly are equivalent to the two together. To examine this minimum more closely readings were taken at intervals of one centimeter. There is no doubt of its existence; it is about 10^{cms} from the end for the smaller oscillators and slightly

* Poincaré, Les Oscillations Électriques, Art. 53.

farther for the larger ones. I find it difficult to give the significance of this.

Other minima were found, but they were not so well-defined. They are, no doubt, due to natural oscillations of the wire, but they are hard to identify.

For the wires 300 and 400$^{cms.}$ long the chief minima are at the middle points.

The question of the dependence of the positions of the minima on the detector is interesting and important; and that there is no such connection was shown in the following way. A second helix, similar to that of the detector, was soldered to the free wire running up beside the one bearing the wing, thus practically doubling the capacity and inductance; but there was no displacement of the minima. The period of the detector must be many times that of the oscillators.

In the near future I hope to apply the magnetic detector to the exploration of much longer wires, in which case the phenomenon of standing waves should be more distinctly shown.

University of Toronto, Toronto, Canada.

ART. IV.—*Rickardite, a New Mineral;* by W. E. FORD.

THE new mineral to be described in this paper was first brought to the writer's attention by Mr. T. A. Rickard of New York. A qualitative examination proved that it contained copper and tellurium, and no such combination having been hitherto described, the mineral seemed worthy of investigation. Through the courtesy of Mr. Rickard, sufficient material was afterward obtained for making a quantitative analysis, the results of which are given below.

Rickardite occurs at Vulcan, Col., in the Good Hope mine owned by Dr. Loui Weiss. The vein mineral is chiefly pyrite, with which occurs native tellurium in unusually large masses, some of which measure fully three inches across. Other associated minerals are petzite, berthierite in imbedded prisms resembling stibnite, and a greenish brown micaceous substance, perhaps roscoelite. A large body of native sulphur also was found in the vein. Rickardite itself occurs in small lense-shaped masses, generally rather intimately associated with native tellurium.

The material for analysis was broken up and carefully gone over by hand to free it from any adhering gangue and only perfectly clean and homogeneous fragments were used. The method of analysis was simple. The powdered mineral was oxidized by nitric acid, which was subsequently removed by evaporation with sulphuric acid. To the strong sulphuric acid solution a liberal amount of hydrochloric acid was added and then sulphur dioxide gas was led into the solution, which precipitated the tellurium in metallic form. This precipitate was filtered onto a Gooch crucible, dried in the air bath at 100° C. and then weighed. In the filtrate copper was precipitated by hydrogen sulphide and determined as cuprous sulphide by igniting in a stream of hydrogen. Careful tests were made for gold, silver, lead, selenium, sulphur, arsenic and antimony with only negative results.

The analysis follows:

	I.	II.	Average.	Atomic ratios.
Cu=	40·68	40·81	40·74	·6469=4·00
Te=	59·36	59·06	59·21	·4737=2·93
Total	100·04	99·87	99·95	

These results give the ratio Cu : Te=4·00 : 2·93, or very nearly 4·00 : 3·00, and the formula for rickardite therefore is Cu_4Te_3. This gives as the theoretical composition of the mineral, Cu=40·51; Te=59·49, which agrees very closely

with the analytical determinations. Rickardite is therefore not only a new mineral but also a new type of telluride, for no such four to three relation between metal and tellurium has hitherto been noted in the group of tellurides. The mineral may be regarded as consisting of one molecule of cuprous telluride and two of cupric telluride, $Cu_2Te.2CuTe$.

Rickardite has an unusual and beautiful purple color, which rivals in intensity the deepest purple tarnish ever seen on chalcopyrite or bornite. The color, however, in the case of Rickardite is not due to any tarnish, for it shows on a fresh fracture and the powder of the mineral, even when ground very fine, is of the same deep color. The mineral is massive in character with an irregular fracture. Its hardness is 3·5 and its specific gravity was determined as 7·54. It is fusible at 1 and gives a pale azure blue flame color tinged in the outer parts with green. Alone on charcoal before the blowpipe it gives a white coating of TeO_2 and fuses to a brittle globule of copper telluride. Fused with sodium carbonate and borax on charcoal it gives a coating of TeO_2 and a brittle globule of telluride, yielding only with considerable difficulty a malleable globule of copper. Roasted in the open tube the mineral fuses to a semi-transparent mass of brown color, which is apparently some combination of the oxides of tellurium and copper, and only a faint sublimate of TeO_2 is formed on the walls of the tube. Heated in the closed tube it fuses and undergoes no further change. Heated in concentrated sulphuric acid it gives the characteristic reddish-violet color of tellurium. When dissolved in nitric acid, the solution neutralized with ammonium hydroxide gives the deep blue color of copper.

It is a pleasure to name the mineral Rickardite after Mr. T. A. Rickard, the editor of the Engineering and Mining Journal of New York, who obtained the material for investigation and supplied the data as to its occurrence. Thanks are also due Dr. Weiss of the Good Hope mine, who has been careful to secure all specimens which might be of scientific interest. In conclusion, the writer wishes to express his indebtedness to Prof. S. L. Penfield for his constant advice and assistance during the preparation of this article.

Sheffield Laboratory of Mineralogy,
Yale University, New Haven.

ART. V.—*An Occurrence of Free Phosphorus in the Saline Township Meteorite;* by OLIVER C. FARRINGTON.

ON drilling into the Saline Township meteorite* recently for the purpose of breaking off a piece, a white "smoke" was observed by the writer to rise from the drill hole when a depth of a little over two inches ($5 \cdot 5^{cm}$) had been reached. This "smoke" had a pungent, garlic-like odor which was recognized as similar to that of white phosphorus. It was more pungent and resembled the odor of burning arsenic to some extent, but on the whole suggested that of phosphorus more. It was at once surmised that phosphorus might exist in the free state in the meteorite, and the supposition was soon confirmed by the following tests:

1. On shielding the eyes from the light and looking into the drill hole, a luminous spot could plainly be seen at the bottom. This spot on further observation showed itself to be actually made up of two. One of these was fixed and central and the other moved around it, making a revolution every two or three seconds. This motion corresponded to the swirling movement with which the fumes rose from the hole and doubtless represented the manner of supply of air to fresh portions of the phosphorus.
2. On holding a strip of paper saturated with silver nitrate in the fumes it turned black in a few moments.
3. On treating some of the powder from the drilling with nitric acid and adding the solution so obtained to ammonium molybdate, the familiar yellow precipitate of ammonium-phospho-molybdate was produced.

The fumes continued to rise from the hole for about two hours when they gradually diminished in volume and disappeared. The odor could, however, be detected eighteen hours afterward. These observations were confirmed by several of my associates. No effort has as yet been made to obtain a quantitative determination of free phosphorus in the meteorite, nor is it likely that results of any particular value could thus be gained. Two holes were drilled the same depth as the first in other parts of the stone, but from neither was any repetition of the above-named phenomena observed. The phosphorus is (or was) probably, therefore, only locally distributed and in small quantity. The stone where broken at the end of the hole first drilled shows a spot about half an inch in diameter differing considerably in color from the rest of the stone, being

* For a brief account of the fall and general characters of this meteorite see Science, N. S. vol. xvi, p. 67, July 11, 1902.

brownish white in contrast to the greenish black hue of the remainder. This portion may prove on further examination, therefore, to be differently constituted. The properties above described are those of free phosphorus, however, and the observations leave no doubt that it existed in the meteorite. This seems to be the first known instance, then, of finding this element existing in the free state in nature.

The occurrence serves to point several conclusions regarding the origin of meteorites, which, while they do not differ from those now generally held by students of these bodies, emphasize opinions which have at times been disputed. First, the meteorite was not formed upon the earth. Second, free oxygen was not present where it was formed. Third, the interior of the meteorite cannot have been subjected to any high degree of heat since its aggregation in the solid state.

Field Columbian Museum,
Chicago, Ill.

OGDEN NICHOLAS ROOD.

Ogden Nicholas Rood, Professor of Physics in Columbia University, New York, died at his residence in New York, on Wednesday, November 12, of pneumonia, after an illness of but a few days. He was at the head of the Department of Physics, and the senior officer in the faculties of the university.

Professor Rood was born in Danbury, Connecticut, Feb. 3, 1831, and was the son of Rev. Anson Rood, a Congregational clergyman, and Aleida Gouverneur (Ogden) Rood. He entered Yale College in 1848 as a member of the Class of 1852, but did not remain longer than one year, subsequently entering Princeton College, where he graduated in 1852. The autumn of this year he spent in New Haven, pursuing scientific courses of study as a graduate student, in the Department of Philosophy and the Arts, of Yale. Although his name appears upon the college catalogue as a member of this department for the two college years 1852–3 and 1853–4, he spent but a portion of this time in New Haven. During several months in the early part of 1853 he was at the University of Virginia, acting as assistant to Professor J. Lawrence Smith. Later in the same year he was for some months in New York, as the assistant of Professor B. Silliman, Jr., who was in charge of the Chemical, Mineralogical and Geological Department of the Crystal Palace, in that city. His scientific tastes had already declared themselves at this time, and his earliest contributions to this Journal were two papers, which he had read before the Berzelius Society of Yale, and which, even thus early, foreshadowed the direction his later studies would take. The first was "On the *Paramecium aurelia*," and gave an account of the microscopic study of the organism. The second was "On a method of exhibiting the Phenomena of Diffraction with the Compound Microscope." Both were published in 1853.

The four years, from 1854 to 1858, were spent in Europe at the universities of Munich and Berlin, in the further prosecution of his scientific studies. On his return to this country, in 1858, he accepted the position of Professor of Chemistry and Physics in Troy University, which he occupied until 1863, when he resigned. The institution had been suffering from lack of resources, and finally ceased to exist. Not long after this he was elected Professor of Physics in Columbia College, entering upon his duties early in 1864. This position he continued to hold during the remainder of his life.

Professor Rood was a born investigator, full of enthusiasm for scientific studies, with an uncommonly clear perception of

the principles involved in physical phenomena, and a keen intuition of the experimental conditions and methods leading to discovery. He was especially apt in the use of simple means for the study of the problems which interested him, often reaching results of great importance and novelty by the skillful combination of pieces of the most ordinary materials, such as are found in the physical laboratory. While apparently caring little for the exhibition of mechanical expertness, or for the attainment of mere elegance of design or finish, he possessed constructive faculties of a high order, in the adaptation of an apparatus for the purpose he had in view. Many of his most striking researches were conducted with scarcely any use of the standard instruments of the laboratory, his experiments being carried out with means improvised for the occasion, and gradually developed to greater and greater elaboration, as new suggestions came to him in the course of the work. In many cases this resulted in notable improvements of familiar apparatus, and the production of instruments of unexampled sensibility, and the attainment of a degree of precision far beyond anything hitherto reached. Excellent examples of this are seen in his improvement of the horizontal pendulum, by which he was enabled to detect and measure changes of dimension in solid bodies as small as the ten millionth part of an inch; in his modification of the Sprengel pump, by which he was able to carry the exhaustion to degrees almost unlimited, and to measure tensions as low as the four hundred millionth of an atmosphere; and finally, in the last research of his life, in which, by the use of an electroscope of the most elementary simplicity, he succeeded in measuring resistances of hundreds of thousands of megohms, and detecting peculiarities of insulating bodies hitherto unknown.

After entering upon his scientific career Professor Rood displayed great activity, and was a frequent contributor to this journal, where most of his papers were published. The number of titles of his communications is about seventy, not counting various minor contributions and notices. Though many of them are quite brief, they would be sufficient, in the aggregate, to form a volume of several hundred pages. The number and variety of these papers forbids anything like a full enumeration here, but some of the more characteristic may be briefly mentioned. While at Troy University he devised certain adaptations of the compound microscope for measuring the angles of crystals, and indices of refraction; studied the stauroscope of Von Kobell, and made new applications of it; observed the singular contraction of the muscles caused by contact with rapidly vibrating bodies, resulting in

a kind of temporary cramp similar to that produced by electric shocks; made many experiments upon the best forms for elongated projectiles, and demonstrated the superiority of American rifled firearms, and American marksmanship; devised a method of producing stereographic pictures by hand; discussed Dove's theory of luster, and devised many new experiments for producing it; studied the practical application of photography to the microscope, and showed how it might be used to determine the character of the minute markings upon diatoms.

The years from 1864 to 1869, after his settlement at Columbia College, were comparatively uneventful so far as publication was concerned, doubtless owing to the great demands of his new position. But, shortly after, a series of valuable researches was begun, and, throughout the rest of his life, contributions appeared in rapid succession. During this period he investigated the nature and duration of the discharge of a Leyden jar connected with an induction coil, and determined with an accuracy hitherto unattained the duration of the bright spark from a jar of small capacity. This work was resumed later, and he showed that the bright spark lasted for a period not longer than forty billionths of a second. He also, in connection with this research, studied the question of the amount of time of illumination necessary to vision, finding that a duration of four billionths of a second was sufficient for distinct vision. The experience gained in these experiments led him to study the character of lightning, using for the purpose a rotating card-board disk, which in his hands proved an efficient instrument of measurement in many applications. He thus, for the first time, determined the duration of the flashes, finding an average value of the five hundredth part of a second, but subject to great variations. He also showed the multiple character of the flashes, and that they often terminated in a single isolated discharge of so short duration as to be, in comparison with the others, practically instantaneous. In this period also were carried out the experiments with the horizontal pendulum, and the Sprengel pump, already referred to, and later the work upon the measurement of high resistances.

He had at intervals been much interested in the study of color, and made many experiments in the measurement of the intensities of colored lights. His first efforts in this direction were made by the help of the rotating disk, in a comparison of the gray from the black and white sectors of variable proportion, so adjusted as to have the same apparent brightness as the object studied. His skill in experimenting enabled him to make consistent observations, and he obtained valuable quantitative results. This subject was a favorite one with him,

and he recurred to it again and again. He was ultimately fortunate in discovering, in 1893, a novel and original photometric method which is independent of color, and which depends upon the shock which the retina receives when one illuminated surface is quickly withdrawn and replaced by another of different brightness. The flickering effect thus produced disappears when the two lights are of equal intensity. This idea he further elaborated later, and in 1899, he published in this Journal an article upon the Flicker Photometer, with a more complete description, and showed by elaborate tests and verifications that the accuracy attainable with this instrument, in comparing differently colored lights, is about the same as for white, or like colors, in the ordinary photometer. He applied it also with great effect in the study of color-blindness, and brought out, with striking emphasis, the interesting fact that eyes supposed to be normal differ greatly in their perception of colors, and that it is rare to find two persons who agree in their color vision.

Another subject which received much attention from him was the study of the character of various complex colors, especially those of the different pigments, and he devised a system by which it was possible to express the composition of such colors by the proportion of certain standard colors in their make up, thus for the first time introducing definite quantitative methods in the study of color and color-contrasts.

The results of Professor Rood's studies of color for many years especially fitted him to write a treatise upon the subject, and in 1879 he published a volume entitled "Modern Chromatics, with Applications to Art and Industry" (New York, D. Appleton & Co.), it being one of the volumes of the International Scientific Series. To the title, in a later issue, were added the words, "Student's Text-Book of Color." This addition suggests the purpose and scope of the work, which was intended for the inexperienced student interested in the practical uses of color, as well as for those familiar with the principles of optical science. It is a happy example of clear and simple exposition, that is at the same time of a strictly scientific character. The book is full of interesting suggestions, and the results were carefully verified by innumerable novel and ingenious experiments which were original. It forms an indispensable hand-book for the artist, as well as for those interested in the practical applications of color.

It may be added that Professor Rood's work upon this book was greatly facilitated by his own experience as an artist. As early as his residence in Munich he had practiced painting in oil, and attained a high degree of proficiency. He had great skill in drawing, and became expert in painting in water-colors,

some of his pictures having been shown at the exhibitions of the Academy of Design in New York.

In 1865 Professor Rood was elected to membership in the National Academy of Sciences, which was founded two years before. He was therefore one of the senior members of the Academy, at whose meetings he often presented papers of great interest. He was a Fellow, and, in 1869, Vice-President, of the American Association for the Advancement of Science. He was also a member of the American Philosophical Society, and of various other associations, scientific and social.

At the Bicentennial Celebration of Yale University in October, 1901, the degree of Doctor of Laws was conferred upon Professor Rood "as a pioneer of American Science," an honor seemingly somewhat tardily bestowed. But it is understood that his aversion for public ceremonials and display, and possibly slight valuation of academic distinctions, had led him previously to decline similar honors on more than one occasion.

In his personal qualities Professor Rood was a man of strongly marked individuality. In figure and manner there was much of native distinction, while his countenance, often grave, even sombre, and piercing eye, conveyed the impression of great intellectual force and keenness. He had an unusual power of piquant and interesting conversation, which was displayed most agreeably in the company of congenial friends. His grave demeanor was often a mask for a vein of humor which was one of his strong characteristics, and which, if often mischievous, and sometimes rather grim, was not often misapprehended by those who knew him well. His detestation of shams and commercialism in science was intense, and his expression of it both frank and forcible. While apparently not greatly caring for general social activities, and in his devotion to his scientific occupations having somewhat the way of a recluse, he was most hospitable and cordial to his scientific friends, and did many acts of spontaneous and unexpected kindness, which revealed the warmth of feeling hidden beneath his reserve. To his younger colleagues especially he showed great friendliness, and his generous estimation of their work, and cordial appreciation, were most encouraging and helpful. To all such his departure leaves a permanent sense of loss, as it must to the university he served so long and honorably.

Professor Rood was married, in 1858, to Miss Matilde Prunner, of Munich, who survives him, with three daughters and two sons.

Arthur W. Wright.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Properties of Radium.*—Giesel has recently announced that radium gives a pure carmine-red flame-color, which gives a brilliant spectrum. This flame-spectrum is remarkably different from Demarçay's spark-spectrum, since two broad, intense lines occur in the orange-red while the spark-spectrum shows only very faint lines in this region. He has observed also that pure radium bromide, as well as the salt containing barium, gives off bromine continually, while the air in contact with the salt becomes ozonized. This liberation of bromine is accompanied by the appearance of an alkaline reaction (radium hydroxide) and the gradual formation of radium carbonate by the action of atmospheric carbon dioxide. When radium bromide thus gradually decomposes, a gas is produced, and the crystals contain a part of it in an occluded condition. Upon dissolving the crystals in water they become milky at first and give off the gas with a crackling sound. A solution of radium bromide behaves similarly to the solid substance; it becomes yellow from free bromine, which remains dissolved, and a colorless gas is constantly evolved. It seemed probable to Giesel that this gas was hydrogen (although oxygen rather than hydrogen would be expected to accompany bromine), but a sample of it when mixed with one-third of its volume of oxygen did not explode when brought into contact with a flame. It is not yet known what this gas is, but a spectroscopic examination of it is to be made. As would be expected from the investigations of Curie, the gas is exceedingly active, causing phosphorescence and darkening the glass with which it comes in contact. It is suggested that this may be a new gas derived from radium, and that it may be connected with the remarkable inductive action of this substance. It was found that pure anhydrous radium bromide at first phosphoresces with a magnificent bluish light which gives a continuous spectrum. The phosphorescence diminishes after a day or so in consequence of the substance becoming colored, but the activity can be temporarily restored by heating and thus decolorizing the salt, although the phosphorescence becomes continually weaker. The pure radium bromide used in the experiments that have been mentioned gives off Becquerel's rays to a marked degree. Previously fused alkali-metal halides are colored by them in a few minutes.—*Berichte*, xxxv, 3608. H. L. W.

2. *Radio-activity of Uranium.*—It was shown some time ago by Crookes that by simple chemical means uranium could be obtained which was inactive to the photographic film, while the whole of the photographic activity could be concentrated in a small residue, not containing uranium, to which the symbol UrX was given. Frederick Soddy has now confirmed Crookes's

results as far as the photographic activity is concerned, but he finds, when the products are tested by means of the electrometer, that the UrX part is almost inactive while the uranium part retains its activity. The conclusion is reached, agreeing with the observations of Rutherford, that uranium possesses two distinct kinds of radiation, one of which (α) is absorbed very readily even by gases and the other (β) is very penetrating in its nature. It was found that after the cathodic (β) rays have been removed by chemical means they are gradually regenerated in the uranium salt.—*Chem. News*, lxxxvi, 199. H. L. W.

3. *Radio-activity of Thorium.*—In connection with the description of very elaborate researches on the subject, RUTHERFORD and SODDY mention some interesting facts in regard to thorium radio-activity. Besides being active in the same way as uranium compounds, the compounds of thorium continuously emit a gas which possesses the property of temporary radio-activity. This emanation is the source of rays which ionize gases and act upon photographic films. The emanation excites radio-activity on all surfaces with which it comes in contact, and such surfaces behave as if they were covered with an invisible layer of intensely active material. If thoria is exposed to a strong electric field, the excited radio-activity is entirely confined to the negatively charged surface, and in this way it is possible to concentrate it on a very small area. The excited radio-activity is removed by rubbing, or by the action of acids. If the acids be then evaporated, the radio-activity remains on the dish. It appears from these facts that minute quantities of special kinds of matter in the radio-active state are given off by thorium compounds.—*Phil. Mag.*, 1902, 370. H. L. W.

4. *Metallurgical Laboratory Notes;* by HENRY M. HOWE. 8vo, pp. 140. Boston, 1902 (Boston Testing Laboratories).—This is a course of laboratory instruction for students. The author, very wisely it seems, has avoided the attempt to reproduce industrial processes as a whole, but has aimed to teach the underlying principles. His reasons for this plan are well put as follows: "For the details of practice are learnt inevitably, spontaneously, accurately and with the greatest ease in practice itself, but with very great difficulty and distortion in the laboratory. Principles, on the other hand, are what the laboratory teaches most readily and perfectly, and practice least readily and most imperfectly." The book contains a series of very suggestive experiments, many of which are quantitative in their character, and the work evidently marks an advance in metallurgical instruction. H. L. W.

5. *The Analysis of Steel-works Materials;* by BREARLEY and IBBOTSON. 8vo, pp. 501. London, 1902 (Longmans, Green and Co.).—The wide scope of this book is seen from the following list of the parts into which it is divided: The analysis of steel, of pig-iron, of steel-making alloys; rapid analysis at the furnace; the analysis of ores, of refractory materials, of slags, of fuel;

boiler water, boiler scales, etc.; analysis of engineering alloys; micrographic analysis of steel; pyrometry; miscellaneous notes; bibliography of steel-works' analysis. The authors give full descriptions of the analytical methods which they prefer, and also give summaries of other important methods. The bibliography is elaborate and will be useful, although it refers chiefly to British journals. The book is supplied with many illustrations.

H. L. W.

6. *Electro-chemical Analysis;* by EDGAR F. SMITH. Third edition, revised and enlarged. 8vo, pp. 204. Philadelphia, 1902 (P. Blakiston's Son & Co.).—The appearance of an improved edition of Professor Smith's well-known, excellent book is to be heartily welcomed. The work has been much enlarged, and the section devoted to separations has been entirely recast. H. L. W.

7. *The Potash Salts;* by Dr. L. A. GROTH. 8vo, pp. 291. London, 1902 (The Lombard Press).—This book gives an interesting and instructive account of the great German potash industry, including the history of its development, the geology and mineralogy of the deposits and many statistics. It also treats of the applications of potash in industry, agriculture and horticulture. Descriptions of various kinds of mining machinery are also given.

H. L. W.

8. *Elektro-Metallurgie;* von Dr. W. BROCHERS, Dritte Auflage, Erste Abtheilung. 8vo, pp. 288. Leipsic, 1902 (S. Hirzel).—This is the first part of the third edition, much enlarged and thoroughly revised, of a very important work on elektro-metallurgy. The rapid development of this branch of industry makes its description increasingly difficult, but it is evident that the author has accomplished this well. The part under consideration treats of the alkali, alkali-earth, and earth metals, also of copper and partly of nickel. H. L. W.

9. *Physikalische Chemie der Zelle und der Gewebe;* by Dr. RUDOLF HÖBER. 8vo, pp. 344. Leipzig, 1902 (Engelmann).—The theories of osmotic pressure, electrolytic dissociation and mass action are presented in about the usual manner but with constant application to life processes. The work of Loeb on the effects of ions and their electric charges receives favorable notice. The methods used in physico-chemical research are given at some length. Ferments, both organic and inorganic, are discussed, Bredig's work in particular on this subject being reviewed. A short chapter is devoted to the influence of temperature and pressure on equilibria.

The book should be of service to those who are interested in physiological chemistry, where it is not improbable that much progress will be made in the future by applying the theories of physical chemistry. H. W. F.

10. *Electrical Properties of Thin Metal Films.*—Professor J. PATTERSON obtained metallic films by cathode discharges in vacuo on glass strips. The thickness of the metallic deposit was measured by Wiener's interference method (Wied. Ann. xxxi,

p. 629) and a complete account is given of the method of measuring the resistances of the films. The conclusions are as follows:

(1) The specific resistance of the films deposited in vacuo by the cathode discharge is several times greater than the specific resistance of the metal from which they were deposited.

(2) The specific resistance of platinum films which have been subjected to the same treatment remains constant above a thickness of about 7×10^{-7} cm. Below this thickness the increase of specific resistance with decrease in thickness is very rapid.

(3) Heat decreases the resistance of both silver and platinum films, and the thinner the film the greater the decrease. In platinum films the greatest decrease is produced by the electric current.

(4) The values obtained for λ, the mean free path of the corpuscle in the metal, are of the same order as those obtained from the change of resistance produced by a transverse magnetic field. —*Phil. Mag.*, Dec., 1902, pp. 652–678. J. T.

11. *Formation of Ozone by Electrical Discharges in Oxygen.*—E. Warbury finds that the amount of ozone obtained from the negative discharge is nearly three times that from the positive. An expression is given for the amount of ozone formed.—*Ann. der Physik*, No. 12, 1902, pp. 781–792. J. T.

12. *Examination of Spectroscopic Methods.*—H. Konen examines the light of various metals produced in liquids—first by the voltaic arc, and secondly by discharges from an induction coil. He refers to the recent observations of Wilsing, and also to those of Hale and Lockyer. He is not able to repeat all the phenomena observed by these investigators, possibly on account of not employing the same conditions.—*Ann. der Physik*, No. 12, 1902, pp. 742–780. J. T.

13. *Does Motion through the Ether cause Double Refraction?*—The negative result of the Michelsen-Morley experiments, and the suggestion of Fitzgerald and Lorentz that the stone platform of Michelsen's apparatus altered its relative dimension when rotated, leads Rayleigh to investigate whether the motion of the ether can cause double refraction. The author concludes from his experiments that there is no double refraction of the order to be expected.—*Phil. Mag.*, Dec., 1902, pp. 678–683. J. T.

14. *Scientia, Série Physico-Mathématique: No. 19, L'Électricité déduite de l'Expérience;* par E. Carvallo. Pp. 91. (C. Naud, Éditeur.)—In a most careful and logical manner M. Carvallo has deduced from the experimental facts of electricity and magnetism the equations of Maxwell's theory and has made clear the significance of the general process employed, by a number of well chosen illustrations. The method is that of Maxwell—the application of Lagrange's dynamical equations to electrical systems—and there is no special originality of treatment; but in clearness of exposition and the avoidance of obscurities the work is admirable and will doubtless make easier the task of many students of Maxwell. A point of special interest is the treatment

of an apparent paradox which occurs in the discussion of Barlow's wheel; a purely mechanical case is given in which there is a similar failure of Lagrange's method for an analogous reason.

No. 20. *Sur les principes fondamentaux de la Théorie des Nombres et de la Geométrie;* par H. LAURENT. Pp. 68.

H. A. B.

15. *Lehrbuch der Physik;* von O. D. CHWOLSON. Deutsche Übersetzung von H. PFLAUM. In vier Bände. Erster Band; pp. xx + 792. (Braunschweig: F. Vieweg & Sohn.)—In 1897 a text-book of physics, in Russian, by Prof. Chwolson of the University of St. Petersburg, was published, and a second and revised edition appeared in 1900. In the meanwhile the work had received such high praise from physicists whose knowledge of the language permitted them to read it that a German translation was undertaken, the first volume of which has recently been issued. Although of large size and comprehensive in character, the work is primarily a text-book for students rather than a rival of such works of reference as Winkelmann's Hand-book; and it is for its pedagogical excellences that it has been especially commended. An examination of the present volume goes far toward justifying in the mind of the reader these commendations; the arrangement and classification are logical and especially convenient for teaching; the statements are clear and exact with most careful discrimination between experimental fact and hypothesis, and the mathematical demonstrations are simple and elegant. But the most striking achievement of the author (considering its difficulty in an elementary text-book) is the constant maintenance of the right point of view and proper perspective; so that the student who uses this book with intelligence can scarcely fail to understand what the object of physics really is, and what are its methods and limitations; the general introduction, in particular, displays these qualities to a marked degree. The second subdivision of the present volume is devoted to mechanics, including wave motion and the elementary theory of potential; the third to apparatus and methods of measurement; the fourth, fifth and sixth to the study of gases, liquids and solids, respectively. The three succeeding volumes in order will deal with sound and radiation, heat, and electricity and magnetism. Although elementary in character, the treatment is very complete, and at the end of each chapter a list of references is given to other books and to the periodical literature of the subject. The book is probably too large and too thorough-going to be used as a text-book in any American college, but it will doubtless be useful indirectly to many teachers. H. A. B.

II. GEOLOGY AND NATURAL HISTORY.

1. *New Mineral Names.*—ANAPITE. A new potassium iron phosphate occurring at Anapa on the Black Sea is given the name Anapite by A. SACHS. The mineral occurs in crystals about

2^{mm} long and $\frac{1}{2}^{mm}$ thick, in plates and radiating columns and also in massive form. It is transparent and of a faint green color. On heating it turns first gray, then black, and finally yellow. Water is given off at 120°. The analysis gave: $FeO = 18{\cdot}07$; $CaO = 27{\cdot}77$; $P_2O_5 = 35{\cdot}51$; $H_2O = 18{\cdot}47$; alkalies, a trace; total $= 99{\cdot}82$. The formula derived from these results is: $FeCa_2(PO_4)_2{\cdot}4H_2O$. The mineral is easily soluble in HCl and HNO_3. $H = 3–4$. Sp. gr. $= 2{\cdot}81$. Crystallization is triclinic, $a:b:c = 0{\cdot}87566:1:0{\cdot}59753$, $\alpha = 132° 22'$, $\beta = 106° 47'$, $\gamma = 83° 28'$. Anapite is closely related to messalite but is not identical with it.—*Sitz.-Ber. preuss. Akad. d. Wissensch.*, Berlin, 1902, p. 18–21.

CHALMERSITE. This new sulphide, which is described by E. HUSSAK, is a member of the chalcocite group. It was found in the gold mine "Morro Velho," in Minas Geraes, Brazil, where it occurs intimately associated with pyrrhotite and chalcopyrite. It is orthorhombic in crystallization with the axial relations $a:b:c = 0{\cdot}5734:1:0{\cdot}9649$, which are very close to those of chalcocite. The common forms found on its crystals are m (110), b (010), c (001), p (111), g (011) and, more rarely, a (100). When the crystals appear doubly terminated they show a hemimorphic development having a base at one end and various pyramid and dome faces at the other. Simple crystals are rare, twins with the twinning plane m being most common. Contact and cruciform twins are rarer. The crystals are almost always prismatic, occurring in needle-like forms. The faces of the prism zone are strongly striated vertically. It has no cleavage; hardness $= 3{\cdot}5$. Luster is metallic, color bronze yellow, often with a brilliant tarnish. It is strongly magnetic. Specific gravity $= 4{\cdot}68$. The quantitative analysis by W. Florence gave, $Fe = 46{\cdot}95$; $Cu = 17{\cdot}04$; $S = 35{\cdot}30$; total $= 99{\cdot}29$, which yields the ratio of $Fe:Cu:S = 3:1:4$. From this is derived the formula: $Cu_2Fe_6S_8$ or $Cu_2S{\cdot}Fe_6S_7$. Named after G. Chalmers, superintendent of the "Morro Velho" mine. —*Centralblatt f. Min., Geol. u. Palaeon.*, No. 3, 1902, p. 69.

KOENENITE. This mineral, which occurs at Volpriehausen in Solling, is described by F. RINNE. It is of a red color resembling some varieties of carnallite, from which it differs, however, in having a fine cleavage. Specific gravity is 1·98. Its crystallization is hexagonal rhombohedral. The analyses show it to be an aluminum, magnesium oxychloride, with varying amounts of water. The formula is $Al_2O_3{\cdot}3MgO{\cdot}2MgCl_2$ with 8 or 6 H_2O. Named after Dr. A. v. Koenen.—*Centralblatt f. Min., Geol. u. Palaeon.*, No. 16, 1902, p. 493. W. E. F.

2. *New Forms on Sperrylite;* by GOLDSMITH and NICOL. (Communicated.)—The following new forms have been observed on crystals of sperrylite from the original locality, "Vermilion Mine," Algoma, Ont.: b, $\bar{2}03$; g, $\bar{2}05$; a, 103; k, 114; m, 113; q, 112; B, 335; and u, 212.

3. *Recherches géologique et pétrographique sur l'Oural du Nord dans la Rastesskaya et Kizelowskaya-Datcha (Perm, Russie);* par L. DUPARC et F. PEARCE. (Mem. Soc. Phys. et d'Hist. nat. de Genève, vol. xxxiv, fas. 2, 4°, pp. 218, pl. 4 and

many figs. in text. Geneva, 1902.)—In addition to the more technical researches in geology comprising the major portion of this volume, it contains also a general account of the region studied, of its physical geography, its orography, hydrography, sketches of its fauna, flora, inhabitants, etc.

The second part of the work treats of the geology and petrography of Mount Koswinsky and the concluding portion is devoted to a similar study of the small mountain Katečhersky. The geology is chiefly the description of the occurrence of the various igneous rocks of the region, which are quite fully described in the petrographical portions of the memoir. They comprise various types of mostly basic rocks, diabases, gabbros, dunites, etc., and diorites, pyroxenites, etc., occurring in dike forms. Of these rocks perhaps the greatest interest attaches to a type of pyroxenites called *Koswite* by the author. It is a melanocratic, granular rock composed of varieties of pyroxene, olivine, hornblende, chromiferous spinels and magnetite; the latter mineral plays the part of the xenomorphic cement.

Several analyses of the different types of koswite are given, from which we select the two following:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Ign.	MnO	Cr_2O_3	
(*a*)	41·44	5·80	10·46	9·98	13·36	19·53	0·22	0·05	0·57	= 101·36
(*b*)	40·15	4·60	12·24	10·87	15·01	17·26	0·40	...	0·58	= 101·11

Very noticeable in these is the enormous amount of iron and the large amount of lime in comparison with the magnesia; these are magmas of types quite distinct from those of most of the peridotites. L. V. P.

4. *Mineralogy;* by HENRY A. MIERS, Professor of Mineralogy in the University of Oxford. 8vo, pp. 584. London, 1902 (The Macmillan Co.).—As stated by the author in his preface the volume is not intended as an exhaustive book of reference, but rather a treatise in which the student will find all that is required for an elementary acquaintance with the subject of mineralogy, the species described being those which may be found in all museums, and most of which may be collected by the students themselves. Special stress is laid upon accurate measurements and determinations, and the intelligent use of the goniometer and microscope. After a brief introduction the subject of crystallization is treated in a thoroughly scientific manner, yet too briefly, it is believed, to satisfy the wants of elementary students. The chapters on the regular conjunction of crystals, on vicinal faces, on the measurement of crystals and on the physical properties characteristic of crystals are brief, but admirably illustrated and full of useful suggestions. The chapter on the optical properties of crystals is one of the best features of the book, and is a very exhaustive and suggestive presentation of this most important subject. By the use of the indicatrix many obscure and perplexing phenomena of uniaxial and biaxial crystals are explained. Following are short chapters treating of the general physical properties of minerals, chemical properties, isomorphism, pyrognostic and microchemical tests, and spectroscopic examination.

About one-half of the book is devoted to the description of the more important mineral species. The descriptions have been very carefully written and give much information which will be welcomed by all advanced students of mineralogy. A noteworthy feature of the book is the large number of excellent, shaded, half-tone illustrations of crystals and crystal aggregates, skilfully drawn by the author's sister, Miss J. Miers. The ordinary outline crystal figures are also well executed, and the text is fully illustrated, there being in all 666 figures and two colored plates.

At the close of the volume there are useful lists of the principal minerals, tabulated according to the chemical classification; according to their mean refractive index in sodium light; birefringence; divergence of the optical axes, 2E, 2V, and 2H; lastly, according to specific gravity. The volume is well printed on excellent quality of paper, and in this respect may well serve as a model for books of its kind. S. L. P.

5. *Zur Fossilen Flora der Polarländer;* von A. G. Nathorst. Erster Teil. Dritte Lieferung: *Zur Oberdevonischen Flora der Bären-Insel* (mit 14 Tafeln). Kongl. Svenska Vetenskaps-Akademiens Handlingar, Bandet 36, No. 3. Stockholm, 1902.—The great age of the plants described in this contribution gives it an especial interest. The Bear Island lies about midway between the North Cape and Spitzbergen. And certain fossil plants described from it by Heer thirty years ago were considered as being of Carboniferous age. Nathorst, however, finds from both faunal and floral evidences that the several beds from which he has in the past few years secured upwards of thirty species of Filicales, Sphenophyllales, Calamariales, and Lycopodiales, are Upper Devonian. He says: "One needs but to inspect briefly the florula of the Bear Island to see that vascular plants must have existed for an exceedingly long period previous to Upper Devonian time." G. R. W.

6. *Beiträge zur Kenntniss einiger Mesozoischen Cycadophyten* (mit 3 Tafeln und 1 Textfigur); von A. G. Nathorst. Kongl. Svenska Vetenskaps-Akademiens Handlingar, Bandet 36, No. 4. Stockholm, 1902.—In the foregoing paper Nathorst describes an exceedingly interesting series of cycadaceous fructifications, in part accompanied by stems or leaves, all of which are of late Triassic age. That very important fossil *Williamsonia angustifolia* Nathorst (=Anomozamites minor) from the Upper Keuper sandstones of Hör in Skone is redescribed from additional specimens, and many figures are given. This plant has a slender, freely branching stem, *Nilssonia*-like leaves, and fructifications that are obviously Bennettitean. It is highly suggestive of the wide range of form that the Bennettites-like plants must have exhibited. Among the specimens figured and described there are some unmistakable ovulate strobili of the *Williamsonia* and *Bennettites* type. As compared with either of these genera there are no fundamental differences apparent in these fruits. Like-

wise, in the case of the somewhat different accompanying fructification often found attached in the forks of the stems, the reviewer believes with Nathorst that a bisporangiate strobilus with shed staminate organs is represented, and that the central pear-shaped axis is ovulate, and may or may not have been functional. It was probably not functional, but one cannot yet say positively whether this plant was monoecious, dioecious, or bisexual, etc. But to continue to include it in the genus *Williamsonia*, the reviewer believes to be inadvisable. In the first place the striking differences of stem and leaf might well in themselves be held of generic value. Also the unknown microsporophylls may have varied considerably from those of *Williamsonia* and *Bennettites*. For instance, though more ancient, they may have been more reduced and stamen-like in form.

Among the other cycadaceous forms described the isolated fruit, considered as representing the new genus *Cycadocephalus*, is also of much interest. If, as Professor Nathorst believes, this fossil consists in a series of basally adnate carpellary leaves, it is certainly generically different from all other known cycadaceous plants. But I am strongly of the opinion that it is a partially expanded bisporangiate strobilus like that of *Bennettites*, and that the elliptical bodies to be seen ranked along the sides of the exposed sporophyll rachis, at several points, are simply large and flattened pollen-bearing synangia. That a true Carpellary or Seed-bearing Disk may have been borne by some extinct cycadaceous plant is indeed both possible and probable, an opinion I have emphasized before. But as yet it does not seem that we have indisputable evidence of any such. As I have stated before, I would rather regard Williamson's so-called carpellary disk as staminate and not seed-bearing. The regularly arranged scars which he doubtless saw on the rays or fronds of certain specimens may better be considered to have been left by fugacious synangia-bearing pinnules than by shed seeds. Whether the fronds in the specimen described by Professor Nathorst are once pinnate or not, is, I think, not disclosed. But I may add that by developing a bisporangiate Bennettitean strobilus from its matrix of bracts I have found quite similar surface details.

The discovery of "Antherangia" in the leafy crown constituting the type of *Dioönites spectabilis* "suggests the existence of another class of Cycadophytes,—the Dioönitales." It would seem possible that pollen might be found in some of the sporangia, and it is much to be hoped that other material may be secured illustrating this unique type of fructification. G. R. W.

7. *A Flora of the South Fork of Kings River;* by Alice Eastwood. 96 pp., 6 figs. Publ. No. 27, Sierra Mountain Club.—Miss Eastwood's Flora of the South Fork of Kings River from Millwood to the Headwaters of Bubbs Creek is the twenty-seventh of a series of publications of the Sierra Club, an association with the following admirable purposes: "to explore, enjoy, and render accessible the mountain regions of the Pacific Coast;

to publish authentic information concerning them; to enlist the support and coöperation of the people and Government in preserving the forests and other natural features of the Sierra Nevada Mountains." The publication as a local flora is unusual in character, for although it relates to a region little explored botanically, rarely visited, and accessible only by pack-train, the paper has been very carefully elaborated as a descriptive flora with ordinal and generic keys and a pretty full characterization of each species. No claim of completeness is made. As in most local floras, the bryophytes and thallophytes are omitted. Furthermore, the grasses, sedges, and rushes, being groups of too great technicality to be of special interest to the tourist, are passed over with brief mention. The descriptions are clear and well contrasted and the author shows excellent judgment in the limitation of species, nomenclature, etc. While fully agreeing with the sentiment expressed in a brief preface, that this flora is far more valuable than the "more descriptive and popular article," which might have been published in the same compass, we cannot help expressing a regret that time and space did not permit some phytogeographic supplement or statistical summary regarding the elements of the interesting vegetation here treated.

B. L. R.

8. *A Botanical Survey of San Jacinto Mountain;* by HARVEY MONROE HALL. Imper. 8vo, 140 pp., 14 pls. (University Press, Berkeley, California.)—Mr. Hall's publication upon the phytogeography of San Jacinto Mountain is of interest from many points of view. It is the first of a new series of scientific papers emanating from the botanical department of the University of California and is at once striking by the excellence of its typography, its clear and attractive illustrations, methodical arrangement, and full index. The region covered by Mr. Hall's studies is one which is well adapted to phytogeographic records, since it exhibits in a pretty restricted area exceedingly diverse climatic and floral conditions, and illustrates with exceptional clearness several well marked life zones. Four of these are delimited with much detail upon a colored contour map of the region. The author has wisely avoided the use of any complex system of phytogeographic terminology and has employed his space to much better advantage by carefully defining the expressions used. The paper closes with a systematic catalogue of the spermatophytes observed on San Jacinto Mountain in and above the yellow pine belt (transition zone). This catalogue, in which several new species and varieties are characterized, not only possesses value as the local flora of a very interesting mountain region, but gives confidence in the thoroughness of the phytogeographic methods of the author, and loses nothing from the fact that it is not lumbered up with needless bibliographical references to common species and well known synonymy. B. L. R.

III. Miscellaneous Scientific Intelligence.

1. *Development and Evolution, including Psychophysical Evolution, Evolution by Orthoplasy, and the theory of Genetic Modes;* by James Mark Baldwin. 395 pp. (The Macmillan Company, 1902.)—A convenient handbook of the theory of Orthoplasy as held by Principal Lloyd Morgan, Professor H. F. Osborne and especially by Professor James Mark Baldwin, is found in a book published under the title Development and Evolution, by the latter author. About half of the volume has appeared in shorter published articles more or less revised in their present form, while the remainder is an expansion of the subject on its psychological side. A brief definition of Organic Selection is given on p. 151: "Organic Selection: the perpetuation and development of congenital variations in consequence of individual accommodations." And the author's point of view may be gathered from a longer quotation. After mentioning objections to both neo-Darwinism and neo-Lamarckism, the author writes: "There is another principle at work whose operation is directly supplementary to natural selection—the principle already described above under the name of Organic Selection. Put very generally, this principle may be stated as follows: acquired characters, or modifications, or individual adaptations,—all that we are familiar with in the earlier papers under the term 'accommodations,'—while not directly inherited, are yet influential in determining the course of evolution indirectly. For such modifications and accommodations keep certain animals alive; in this way occur the variations which they represent from the action of natural selection, and so allow new variations in the same direction to arise in the next and following generations; while variations in other directions are not thus kept alive and so are lost. The species will, therefore, make progress in the same directions as those first marked out by the acquired modifications, and will gradually 'pick up,' by congenital variation, the same characters which were at first only individually acquired. The result will be the same, as to these characters, as if they had been directly inherited," etc. (p. 138.) We reach a more specific and perhaps clearer idea of the author's thesis by noting his phrasing of the means and results of the fourteen different sorts of selection the author has culled from various sources (p. 166). The means of *Natural selection* are listed as *struggle for existence* and *inherent weakness;* the results are *Survival of the fittest individuals,* and (2d) the *Destruction of unfit individuals.* In contrast *Organic selection* has as means *accommodation, modification* and *growth processes,* and the results the *Survival of accommodating and modified individuals.*

From a perusal of the book one is impressed with the multiplicity of forms in which ideas about evolution can be phrased, and with the wonderful evolution of evolution since the publication of the Origin of Species. H. S. W.

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Experiments on artificial good seeing. Smithsonian Astrophysical Observatory.

No. 1. The object, a series of artificial double stars.
2. Image of No. 1, without stirring } exposure, 3 minutes.
3. Image of No. 1, with stirring } exposure, 3 minutes.
4. Image of No. 1, without stirring } exposure, 4 minutes.
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THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VI.—"*Good Seeing*";* by S. P. LANGLEY. (With Plate I.)

EVERY one who has used a telescope knows that our atmosphere is forever in pulsating motion, and troubling our vision of the heavenly bodies, during the most cloudless day or night, so that observatories are put even on high mountains, to get rid of the disturbances in this atmosphere, which tend to make the image of every object tremulous and indefinite, and to prevent what the astronomer terms "good seeing."

I desire to speak to the Academy about a device which I have recently essayed for preventing this universally known and dreaded "boiling" of the telescopic image, a difficulty which has existed always and everywhere since telescopes have been in use, and which has seemed so insurmountable that I believe it has hardly ever been thought of as subject to correction.

Hitherto it has been the endeavor of astronomers, so far as I know, to secure a more tranquil image by keeping the air in the telescope tube, through which the rays pass, as quiet as possible, and for this purpose the walls of the tube have been made non-conducting, and extreme pains have been taken not to set up currents in the tube. With these precautions the "seeing" is perhaps a little better (but very little) than if none were used at all, the main difficulty having been always found insurmountable.

I have been led for some years to consider the conditions under which this "boiling" presents itself. It is not necessarily due to a high temperature of the external air, for the most perfect definition I have ever seen of any terrestrial object was obtained by me long since in the Harvard College Observatory at Cambridge, with its great equatorial telescope, when, on the hottest day that I ever knew in a New England summer, I

* A paper presented to the National Academy of Sciences, November 12, 1902.

directed it with a high power on the distant "south mark," which I expected to find almost indistinguishable from the "boiling." I remember my extreme surprise when, under a magnifying power of 300, I found the image as still as the lines of an engraving. This was an extraordinary exception to ordinary experience, and led me to take an interest in the subject. I have since pursued an inquiry to which this circumstance first directed my attention, and I have done so at all altitudes, at one time residing on Aetna for this purpose, noting that even on high mountains telescopic vision was so far from being always clear that it was sometimes even much worse than at sea level.

I have since come to the important conclusion that while the ordinary "boiling" is due to all the air between us and the sun or star through which the rays pass, the greater portion of it is due to the air immediately near us, probably within a few hundred yards or even feet from the telescope, and this has led me to ask whether it was not possible that some way to act upon this air could be found. Its non-uniformity leads to deformations of the image too complex to analyze here, which are caused not only by lateral vibrations of the cone of rays, but by its elongation and contraction.

For this purpose I have, within the last few months, been making experiments at the Smithsonian Astrophysical Observatory; first with a horizontal tube having three successive walls with air spaces between, which was intended to give the maximum security which freedom from changes of temperature could afford. This observatory being principally concerned with rays best studied in an image formed by reflection, has no large dioptric telescope, on which account these experiments have been made with a reflector. I have no reason to suppose, however, that they will not be equally successful with a dioptric telescope.

A large part of the "boiling" of the image is due to air without the tube, but a not unimportant part to the air within it; and in the preliminary experiments the air, kept still in the tube by treating it with the ordinary precautions, was found to have little effect on the ordinary "boiling" of the image, which so seriously prejudices the definition. An image-forming mirror, fed by a coelostat, was placed at the end of this triple-walled tube, which was itself sheltered by a canvas tent, and contained the stillest air of the most uniform temperature which could be obtained. The "boiling" was but little diminished merely by enclosing the beam by this tube, which was only what had been anticipated from the ordinary experience of all astronomers.

The device which I had determined to try was one of a paradoxical character, for it proposed to substitute for this still air which gave the usual troubled image, agitated air which it

was hoped would give a still image.* For the purpose of this new experiment, the horizontal telescope using a reflector of 40 feet focus, fed by a coelostat through the above tube, was connected with a fan run by an electric motor, which was arranged to draw out the air from the inner tube, at the same time that it forced air in at different points in its length, so as to thus violently disturb and churn the air along all the path of the beam from the coelostat to the solar image.

This first experiment gratifyingly reduced the "boiling" and produced an incontestibly stiller image than when still air was used. As a further test, a series of artificial double stars was now provided, and the concave mirror, acting both as collimator and objective, brought the images to focus, where they were examined with an eyepiece. With the stillest air obtainable, the images were not sharp and only the coarsest doubles were resolvable. Then the blower was started and the definition immediately became sharp. Violently stirring the air in the tube, then, eliminates all or nearly all the "boiling" of the stellar image which arises within the tube itself when using ordinary still air. This experiment concerned the air within the horizontal tube only.

I have next taken up the solar image formed by the mirror in the above tube. This is clearly improved by the stirring. I have also wished to try a tube something like a prolonged dew cap, but which is arranged to be inclined toward the sun. The air in both can be stirred together, but experiment has not yet gone far enough to demonstrate whether it has, as is hoped, any superiority commensurate with the special mechanical difficulties involved.

I am not prepared to give quantitative estimates, which I hope to furnish later; but all observers to whom I have shown these early results on the sun have agreed, that if the "boiling" was not wholly cured, what remained was but a small fraction of that obtained with still air. I have not completed these experiments, which I am still pursuing at the observatory, but they seem to me to give promise of an improvement of universal interest to observers, which justified the making of this early announcement. I had hoped to have shown the Academy some photographs of the sun taken, first, in the ordinary way, and again, with the churned air, but the condition both of the sun and of the sky, of late, has prevented my obtaining them. I can, to my regret, only give here a photograph of the images of the artificial double stars as seen through ordinary conditions, as distinguished from those here mentioned, of artificial "good seeing."

Astrophysical Observatory, Washington, November 12, 1902.

* I may mention here that my lamented friend, Henry C. Draper, once showed me that agitating the contents of a bisulphide of carbon prism improved its definition.

ART. VII. — *Native Arsenic from Montreal;* by NEVIL NORTON EVANS.

AT the end of last July, Mr. Edward Ardley, Assistant at the Peter Redpath Museum, McGill University, Montreal, brought to the writer for identification a mineral found in a vein cutting the nepheline syenite of the Corporation (Forsyth's) Quarry near Montreal. The specimen proved to be native arsenic.* As far as the writer has been able to ascertain, this mineral has been found at but two other localities in Canada: on the west bank of the Fraser River, a short distance above Lillooet, B. C.;† and at Edwards Island, Thunder Bay District, Lake Superior, nine miles east of Silver Islet.‡ The Montreal occurrence is therefore quite remote from those previously recorded, and it was thought that a careful examination and description would prove of interest.

The main portion of Mount Royal is formed of essexite, but a later intrusion of nepheline syenite occurs on the northern slope between the essexite on the one side and the Chazy limestone of the surrounding plain on the other, the limestone having been markedly altered thereby and rendered highly crystalline. The nepheline syenite is grey in color and rather fine in grain, and belongs to the foyaite type of this rock; it is composed of orthoclase, oligoclase, nepheline, and a hornblende very deep green in color, allied to if not identical with hastingsite, together with subordinate amounts of pyroxene, garnet and nosean. The vein containing the arsenic was found traversing the syenite nearly vertically, small horizontal stringers running off here and there, chiefly on one side, and a few veinlets branching off and then running parallel to the main vein. The vein was lenticular in form, having a width of one and three-quarter inches in the widest part, and narrowing down to about one-eighth inch above and below. The thicker portion, which measured about ten feet vertically and three feet horizontally, contained the arsenic, and probably forty pounds of the mineral were removed. There is at present no indication of another widening of the vein lower down, with a further content of arsenic.

Associated with the arsenic were found calcite in considerable quantity, with realgar and pyrites in exceedingly small quantities; in some places, where they occurred in druses, the crystals of calcite (scalenohedra) were sifted over with very

* See this Journal, xiv, 397.

† Ann. Report Geol. Survey, Canada, 1896, part T, p. 9; and 1887–88, part R, pp. 106, 161.

‡ Ferrier: Canadian Record of Science, iv (1890–91), p. 472.

minute black reniform particles, which on account of their extremely small size could not be accurately determined, but which were some silicate of iron soluble in hydrochloric acid and yielding gelatinous silica on evaporation. There were a few little pockets filled with a soft black substance, moist, and hardening on drying in the air. This seemed to be closely allied in composition to the little particles mentioned above, and on its free surfaces it exhibited a similar minute glossy reniform structure.

The arsenic itself is the variety known as "scherbenkobalt"; it is in large masses, often several pounds in weight, formed of concentric layers. It appears as though deposition, probably due to some fumarole action, had started at certain points on the wall of the vein and layer after layer of the arsenic had been added, producing a sort of onion-like lump of the material. In time these masses grew into one another, giving a reniform structure to the whole. Here and there on the surfaces of the masses there are traces of crystalline structure, with angles apparently of 90°; but no faces were found well enough developed to allow of any measurements being taken. The mineral exhibits the usual characteristics of native arsenic; the mean of two analyses gave its composition as:

Arsenic	98·14%
Antimony	1·65
Sulphur	0·16
Insoluble	0·15
	100·10

No silver, bismuth or other element was found, although carefully looked for. Two specimens gave for specific gravity 5·73 and 5·75 at 18°. The hardness is between 3 and 4.

The deposit seems to be notable on account of the purity of the arsenic, its large quantity, and the absence of associated sulphides.

Macdonald Chemical Laboratory,
McGill University, Montreal.

ART. VIII. — *Electromotive Force in Plants;* by AMON B. PLOWMAN.

EVERY disturbance of the atomic relations within any material body is, in all probability, attended by a more or less pronounced electrical disturbance in the ether surrounding the atom. Whether or not this condition of electrical stress can be detected depends upon the amplitude of the atomic displacement, the nature of the body, and the sensitiveness of the instruments used. Thus when copper and zinc plates are placed in a dilute solution of sulphuric acid there is an interchange of atoms between metal and acid, and the rate of interchange is so much greater in the case of zinc that the electrical equilibrium of the system is at once destroyed, and this disturbance is easily shown by means of suitable apparatus. Here, as in all cases, the galvanic current is the manifestation of a difference of atomic activity in two parts of a closed circuit, and this in turn is due to a difference in "solution tension" or "chemical affinity" of the substances employed. The diffusion of liquids is attended by similar electrical phenomenon. For example, when two solutions of different concentration of the same substance are brought in contact, the greater solution tension of the more concentrated solution forces its ions into the weaker solution more rapidly than the ions of the latter move in the opposite direction, and we have what is known as a "concentration element." Since hydrogen and hydroxyl ions take the lead for rapidity of motion in solutions, we find that the more dilute solution of an acid is positively charged ($\overset{+}{H}$) in the concentration element, while the more dilute solution of a base is always negatively charged ($\overset{-}{OH}$).

We may say then, in general, that wherever there are diffusion currents in non-homogeneous liquids, or—even more broadly stated—where there are differences of solution tension in the parts of a material body, there will be electrical differences of a corresponding magnitude.

In view of these facts it is not at all surprising to find that living organisms frequently show well-marked evidence of electrical disturbances within their bodies. Considering the great variety of substances which enter into the composition of an ordinary plant body, the presence of diffusion currents as an ever-essential condition, and the comparatively high resistance offered by living tissues to the passage of electrical currents, it is fair to expect a difference of electrical potential in the parts of such a body when performing its normal functions.

The first systematic study of the electrical properties of plants was made by Prof. J. Burdon Sanderson, in a series of experiments on the electromotive properties of the leaf of Dionæa.* His work was characterized by more than usual care, and while some of his conclusions do not seem to be fully justified by the results, this is in many respects the most satisfactory piece of work in biological physics up to the close of the last century. In order to avoid as far as possible any mechanical injury to the plant, Sanderson used contacts of a paste made of pure clay worked up with a dilute solution of common salt. This mixture was contained in glass tubes leading off to a contact with a saturated solution of zinc sulphate, which in turn was in contact with rods of pure zinc, thus forming so-called "non-polarizable electrodes." With such an arrangement there must be a certain amount of diffusion between the dilute NaCl solution in the clay and the saturated $ZnSO_4$ solution, and in all probability there is more or less diffusion at the leaf-contact itself. So that while this form of contact is probably the best yet devised, it certainly leaves very much to be desired in the way of freedom from possible inherent electromotive force. Where the differences of potential to be measured are of the order of 1×10^{-4} volt, or even much less, it is highly essential that all electromotive force be eliminated from the contact terminals. Sanderson's use of terms in describing electrical conditions is often somewhat vague and confusing. Thus he speaks of relative "positivity" and "negativity" of parts, but fails to state definitely in what sense these terms are used. For example, when he says that "the upper surface is positive to the lower, but that under certain conditions this may change to relative negativity," we have no means of knowing whether he is speaking of the internal circuit or the external circuit. Just as in a Daniell cell, the copper element is positive with reference to the external circuit, and the zinc is positive with reference to the internal circuit, so here such a statement as the one quoted above does not give any information regarding the direction of the current.

The more important conclusions arrived at by Sanderson were, in effect, as follows:

I. In a healthy leaf of Dionæa, in the unexcited state, there is a difference of electrical potential between the upper and under parts of the lobe; the midrib and the lobes; and also between different parts of the midrib.

II. When the leaf is excited this difference of potential between the two surfaces undergoes a sudden reversal of sign, sometimes preceded by a momentary increase of difference in

* Proc. Royal Soc., London, 1881 and 1882. Nature, x, 1874.

the same direction, and followed by a slow return to the normal state.

III. This reversal of sign occurs when the leaf is excited either mechanically or electrically, in the same or the opposite lobe.

IV. Repeated excitation of the leaf reduces the normal difference of potential, and may even reverse its sign for a considerable length of time.

V. Very slight electric shock tends to increase the normal potential difference without reversal of sign and regardless of the direction of the applied current.

VI. In addition to these conclusions, we may readily infer that Sanderson considers the transfer of impulses in the plant as of an electrical nature.

From a repetition of some parts of Sanderson's work it appears that the above conclusions are, in the main, correctly drawn. It is the purpose of this paper to offer some hints as to the explanation, from a purely physical point of view, of the phenomena on which those conclusions are based.

1. As has already been pointed out, it is to be expected that different parts of a living, functionally active plant will show differences of electrical potential. Hence the first conclusion may be accepted without further question.

2. The mechanical closure of the lobes of a Dionæa leaf consists in a sudden loss of turgor by the cells on the upper or inner side of the "hinge," and a slow increase of turgor on the lower side. The disturbance on the upper side is of a truly molar order, while that on the lower side is comparable to molecular movements. The protoplasm of the upper parts may merely cease to be active upon receiving the impulse, or it may undergo a sudden modification before becoming passive. That these changes in condition of the protoplasm, as well as the shifting relations of the cell-sap, excite differences of electrical potential, is highly probable, to say the least.

3. Since the electrical phenomena shown by the excited lobe are the result of its *response* to the stimulus, it is not to be supposed that they will be modified by the varying *source* of the stimulus.

4. Repeated excitation of E.M.F. in the leaf, followed in each case by diffusion of the charge through the tissues, must increase the number of free ions in the solution,* and thus the conductivity is increased. As a result, the slight normal difference of potential is more quickly neutralized and becomes imperceptible. Reversal of sign must apparently be attributed to "fatigue" of the protoplasm in one part of the leaf.

* See paper by A. Crum Brown on "The Ions of Electrolysis," Science, xv, 388.

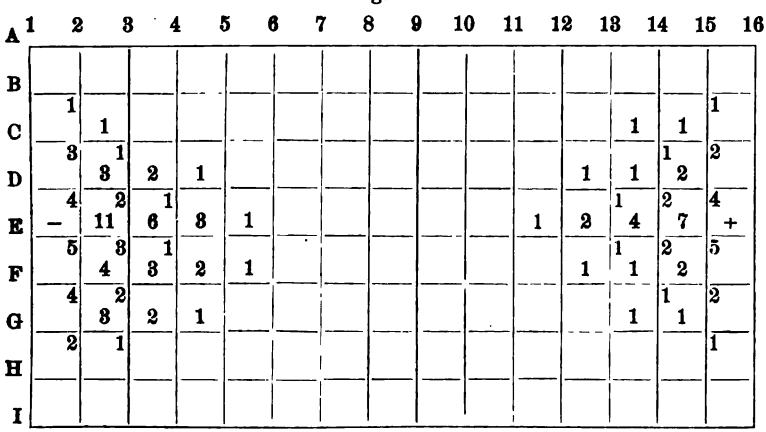
5. Extremely slight electrical shock does not appreciably disturb the degree of dissociation of a solution, and so does not increase its conductivity. But many experiments show that even almost imperceptible shock stimulates protoplasmic activity to a marked degree. In the leaf this increased activity would naturally be more pronounced in the part already active than in that which is comparatively passive.

6. The question of the nature of the transfer of impulses through living protoplasm must remain properly a biological problem until the mechanism of protoplasm itself is more fully understood. That the transfer of an impulse is attended by

Fig. 1.

	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16
A															
B		1	2	2	3	3	4	4	4	4	5	6	5	5	
C		1	3	4	3	3	3	3	3	3	4	5	4	4	
D		2	1	1	2	2	2	2	2	2	3	3	3	3	
E	—	25	5	3	2	2	1	1	1	2	2	4	8	25	+
F		2	2	2	2	2	2	2	2	2	2	3	3	3	
G		1	2	2	1	1	1	1	1	2	2	2	2	3	
H		0	1	1	2	3	4	4	4	4	4	3	3	2	
I															

Fig. 2.



an electrical disturbance, can hardly be questioned. That an electrical shock of slight intensity is capable of exciting the protoplasm is equally certain. Apparently the separation of impulse transference, electromotive force, and protoplasmic response is a difficult problem. If the rate of transfer could be measured accurately it would probably offer a solution. But this, independently of the time of protoplasmic response, has not been measured.

The spreading of an electric current to all parts of a leaf through which it is flowing, and the distribution of the reaction current which follows, may be shown by simple experiments to be precisely analogous to the similar phenomena in non-living bodies.

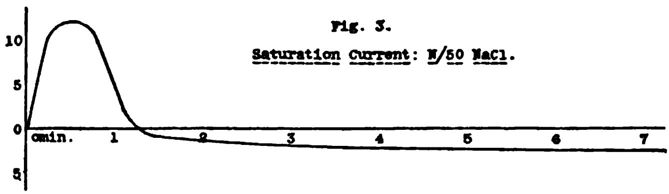


Fig. 1 represents a rectangular piece of filter paper which was saturated with N/50 NaCl, and through which a 1v. ·1 amp. current was passed between the points marked + and —. With galvanometer terminals 1^{cm} apart, the entire field was explored on the lines B, C, D, . . . H. The potential difference in each case is recorded on the line joining the points of contact, and in units of 1×10^{-6} volt. After the battery current was turned off, the field was again explored and recorded in the same units, fig. 2. Values less than unity are not recorded. At no part of the field was the potential difference imperceptible with a galvanometer sensitive to 1×10^{-6} volt. Of course the current flowed in the same direction through the galvanometer as before, since it passed in the *opposite* direction through the paper. (We are inclined to believe that Sanderson was in error on this point in some cases.) From this well-known tendency of the electric current to spread over the entire conductor, it seems quite possible that electrical stimulation of one lobe of Dionæa may spread, as an electrical disturbance, to the other lobe.

The generation of E.M.F. by diffusion and difference of concentration is shown graphically in fig. 3. In this and the following figures the unit potential is 1×10^{-6} volt. Potential differences are always represented by vertical displacement of the curve, while time units are plotted on the horizontal axis. A piece of filter paper 10^{cm} square was rolled tightly, and the platinum-wire terminals of the galvanometer were inserted in the

ends of the roll. So long as the paper was dry there was, of course, no current. Calling one end of the roll "A" and the other "B" we shall represent any current from "A" to "B" through the paper by displacement of the curve upward from the zero line. N/50 NaCl was now added slowly to the paper at "A." When the moisture reached "B" there was a rapid deflection of the mirror, which increased for about 20 sec., then fell to zero at 1 min. 20 sec., then slowly turned in the opposite direction, but not so far as it had gone in the first direction. For an explanation of this we must, no doubt, look to the different diffusion velocities of the free ions in the solution.

The next five figures represent the "reaction currents" of solutions of various salts. In each case a roll of filter paper was arranged as for determining the "saturation current," with the difference that it was uniformly saturated at once. After passing a 3v. current through the roll for one second the galvanometer circuit was closed and the reaction current was noted. Of course the reaction current was always in the direction opposite to that of the battery current, through the paper. The peculiarities of the curves may be readily and satisfactorily explained on the principles of physical chemistry, but our present attention should be directed rather to the striking similarity between these curves and those in figs. 9, 10, 11 and 12, which represent the reaction currents in various plants after forcing a 3v. current through them. The direction of the reaction is always opposed to that of the battery current. A comparison of figs. 5 and 11, 7 and 10, 8 and 9, 6 and 12, makes this similarity fully apparent. The longer action of the forced current in the plants is necessitated by their higher resistance, which means that the compounds in them yield less readily to electrolytic dissociation. The only difference worthy of note is the presence in the plants of a "normal current" of greater or less intensity. All the figures show the temporary reduction of this current by the action of the forced current.

Fig. 12 deserves special notice, since it furnished the first hint of the diurnal variation in the normal plant-current. The plant used in this experiment showed a normal upward current of ·8 between two points 20^{cm} apart on the stem. The usual battery current was passed upward through the stem for 10 min., with the reaction shown at I in the figure. At II the forced current was repeated. Its reaction is slightly more abrupt in neutralization. At III the forced current was again repeated. The reaction was still more abrupt, and also more intense, owing to the increased conductivity of the stem. The recovery of the normal current was slow, and incomplete yet at IV. This was at about 5 P. M. Two hours later the plant was found to have a normal current downward. A forced current in this direction gave

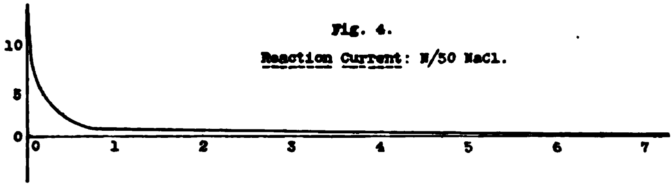


Fig. 4.

Reaction Current: N/50 NaCl.

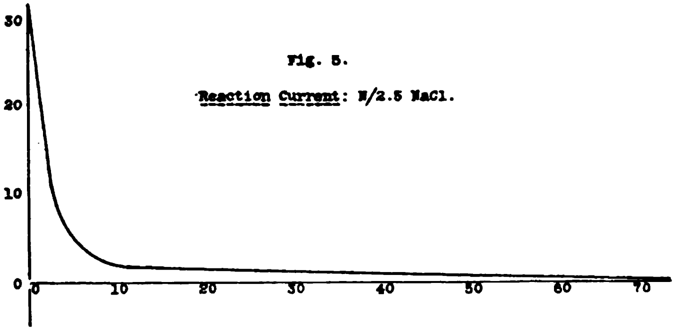


Fig. 5.

Reaction Current: N/2.5 NaCl.

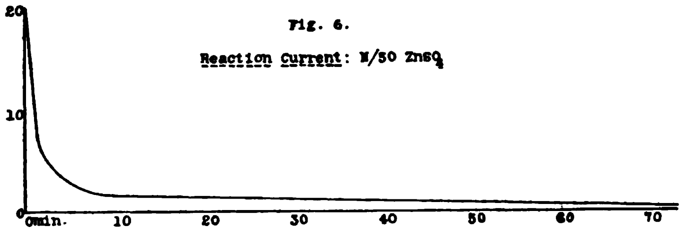


Fig. 6.

Reaction Current: N/50 $ZnSO_4$

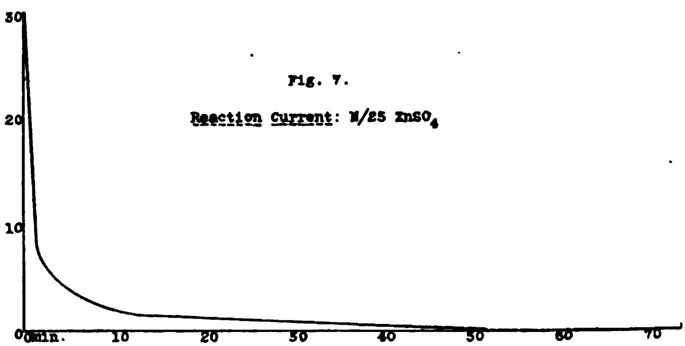


Fig. 7.

Reaction Current: N/25 $ZnSO_4$

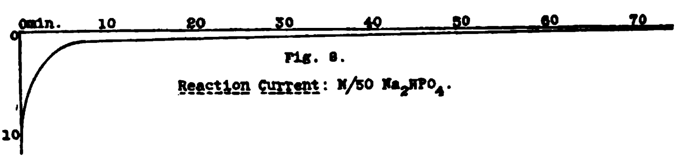


Fig. 8.

Reaction Current: N/50 Na_2HPO_4.

the reaction at V. Since the plant had been resting during the hour before and the hour after sunset, it was thought that its reversal of normal current might be due to a change in physiological activity. Accordingly, a little later in the season a plant was tested for daily variations in its normal current. Fig. 13 shows its behavior in this respect for the first 54 hours after it was removed from the greenhouse to the laboratory. The sudden drop in temperature caused the plant-current to turn downward for a few hours, after which it flowed upward with increasing intensity until about 6 P. M. At 9 A. M. next day the current was downward. At noon no current was present, and then it was upward until 6.30 P. M. With minor variations for temperature-change, this day's record was found to be quite typical. Other experiments also point to the conclusion that when plants are physiologically active the normal current is upward, while in the comparatively passive plant this current is either wanting or downward.

Figs. 14*a* and 14 show the results of a series of experiments to test the effects upon the normal E.M.F. of mechanical injury and heat. The plant showed the usual upward current at 2 P. M. When the stem was heated at the lower contact to 35° C. the intensity of the upward current was increased. Upon cooling this terminal to the normal temperature and heating the upper one the current was reversed, as shown at I. On cooling this terminal the current came back almost to its original condition. Next, light pressure was applied to the stem at the point of contact, with resulting current toward the other contact through the stem, as shown at II in the figure. Piercing the stem near the contacts with a platinum needle produced no perceptible effects on the E.M.F. At III, the terminal points were alternately heated to 40° C. for a very short time. After this test the normal current was reduced to zero. The stem was then crushed midway between contacts with no indication of current. At IV the stem was crushed at the contact, showing a momentary E.M.F. through the stem, away from the point of injury. Heat to 40° C. gave the reaction at V, the current always flowing through the stem from the point of high temperature.

The stem was now completely crushed between the contacts, but no E.M.F. was shown while this was being done. Heat to 40° C. gave VI. At VII the usual battery current was applied. The reaction indicates a higher conductivity than in a normal stem. This is readily explained by the fact that in the crushed stem the intercellular spaces are filled with the cell-sap, which thus forms a conductor of less specific resistance than is met with in the normal condition of the plant, where the electric current must pass through cell walls and films of living protoplasm. At VIII the forced current was repeated, and the reaction indi-

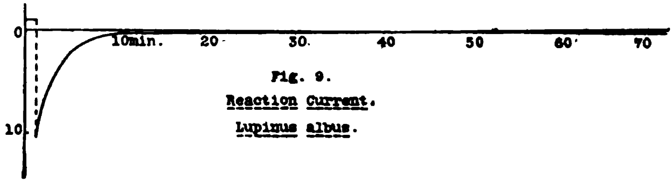


Fig. 9.
Reaction Current.
Lupinus albus.

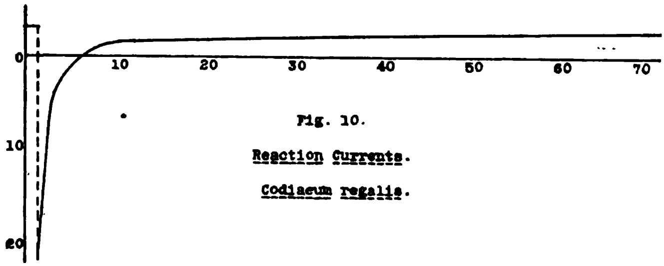


Fig. 10.
Reaction Currents.
Codiaeum regalis.

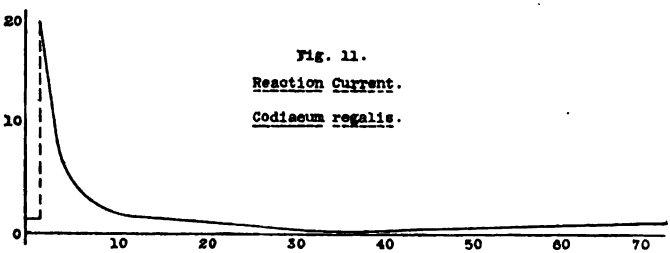


Fig. 11.
Reaction Current.
Codiaeum regalis.

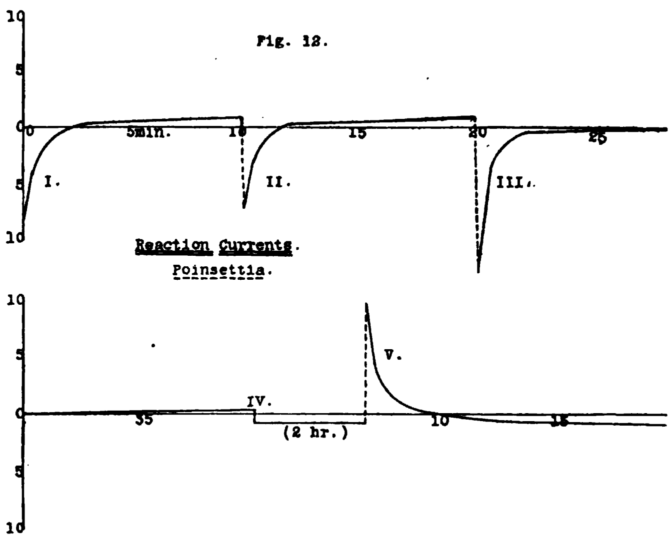
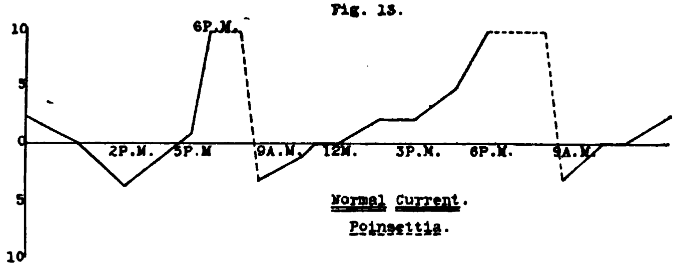


Fig. 12.
Reaction Currents.
Poinsettia.

cates a still further reduction of the resistance. At IX the lower contact point of the stem was heated to ignition over an alcohol flame. The maximum current appeared when the

Fig. 13.



Normal Current.
Poinsettia.

Fig. 14a.
(Poinsettia)

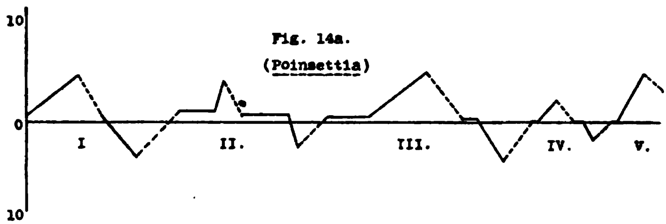
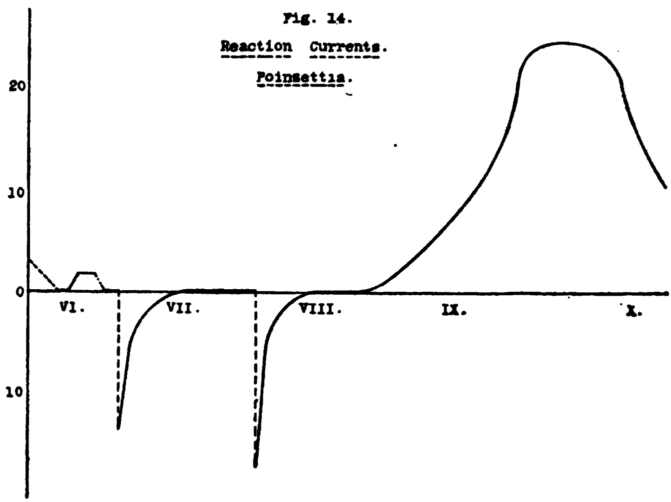


Fig. 14.
Reaction Currents.
Poinsettia.



stem was about two-thirds burned off, after which the current decreased slowly until the stem broke under its own weight at X in the figure.

The explanation of all these phenomena comes naturally within the domain of physical chemistry. Thus, the applica-

tion of heat to any part of the plant,—other conditions being normal,— will invariably increase the physiological activity of that part, so long as the temperature does not exceed a certain optimum degree. Moreover, the increase of temperature is attended by, or rather is due to, an increased kinetic energy of the atoms. But any acceleration of the motions of the atoms in a solution is normally attended by a corresponding increase in dissociation and electrical conductivity. In like manner, slight pressure on the walls of any plant-structure is attended by violent molecular displacements through the cell walls and protoplasmic films. This, also, destroys the kinetic equilibrium of atomic relations, and a local E.M.F. is the natural consequence. Temperatures above a certain maximum kill the protoplasm, and the "normal plant-current," which is an index of physiological activity, necessarily disappears. We have now to deal with dead protoplasm, and the only difference in reaction worthy of note is a slight decrease in specific resistance of the tissues, due to a more ready diffusion of the conducting liquids.

These few experiments, while they are of a preliminary and very general character, seem to point with a fair degree of certainty to the following conclusions:

1. The functional activities of a plant give rise to differences of electrical potential in its parts.

2. The intensity and relative sign of these differences depend upon the physiological condition of the plant, as well as upon its electrical conductivity.

3. The normal E.M.F. in a plant may be modified in intensity or direction by brief application of forced currents. This appears to be due in part to a change in resistance, and in part to a modification in the vital activity of the protoplasm.

4. Slight mechanical injuries do not perceptibly modify the normal current.

5. Extensive mechanical injuries or high temperatures destroy the normal current, but do not modify the reaction current, except by a slight increase in the conductivity of the tissues.

6. Extensive injuries to a plant excite an E.M.F. spreading from the point of injury through the tissues.

7. "Reaction currents," in the sense in which this term is used in this paper, depend but little, if at all, upon the vitality of the plant, and can be duplicated in non-living substances.

Harvard University,
Cambridge, Mass.

Art. IX.—*The Ionization of Water Nuclei;* by C. Barus.

1. *Introductory.*—In my report to the Smithsonian Institution (August, 1902) and elsewhere,* I pointed out the desirability of further investigations on the Lenard† effect. While my work in this direction was in progress, a paper due to J. J. Thomson appeared, covering similar ground. Nevertheless I shall venture to publish the following results since the subject is looked at from a somewhat different point of view, obtained

1

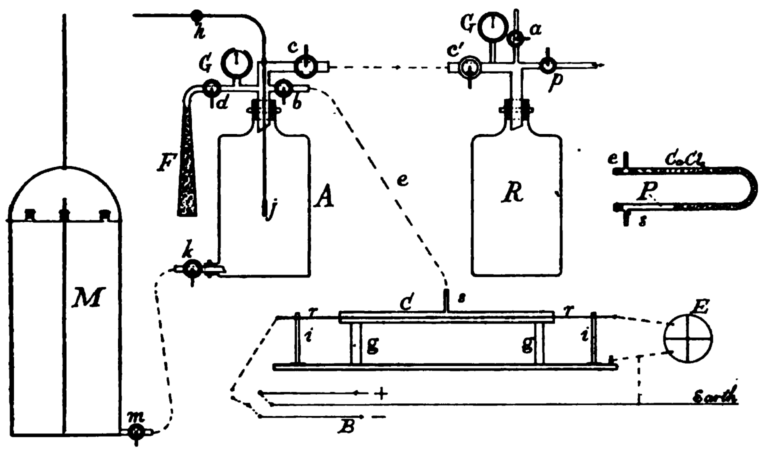


Figure 1. Apparatus for comparing nucleation and ionization; *A*, coronal chamber; *R*, exhaustion reservoir; *M*, Mariotte flask; *C*, tubular condenser; *P* (to be inserted in the conveyance tube, *e*) phosphorus ionizer; *G*, *G′*, vacuum gauges; *F*, cotton filter; B, storage battery terminals. Tubes *p* to suction pump; *a*, to atmosphere; *c*, *c′*, for exhaustion; *e*, for conveying the nuclei into the condenser; *d*, for filtration; *h*, from the hydrant. Extremely fine jets of water shoot out from the needle pricked lead pipe, *j*. Supports *g*, *g* are metallic; *i*, *i*, insulating.

from coronal and other measurements. My chief purpose, however, is to find whether as a result of Thomson's‡ remarkable discovery of radio-activity associated with water nuclei, the theory given in my "Experiments with Ionized Air"§ is to be abandoned. The experiments of this paper show, I think, that this is not necessary. They contain, it seems to me, an interesting confirmation of the views stated in the third

* Science, xvi, p. 633, 1902.
† Lenard, Wied. Ann., xlvi, p. 584, 1892.
‡ J. J. Thomson: Experiments with Induced-radio-activity of Air, and on the Electrical Conduction Produced in Gases When they Pass through Water; Phil. Mag. (6), iv, p. 352, Sept., 1902.
§ Smithsonian Contributions, No. 1309, 1901.

chapter of my memoir, and lead to an explanation of the electrical behavior of water nuclei, so far as it is here in question, which is free from new hypotheses.

2. *Apparatus.*—If in the receiver, or condensation chamber, *A*, the cock, *b*, is joined with *s* by a metallic pipe, *e*, leading directly to the tubular condenser *C* (radii 1·05 and ·32^{cm}, length, 50^{cm}), the apparatus takes the form of figure 1, adapted for measuring the initial ionization of the nuclei. If the cocks *k* and *d* (filter) are closed and the fine radial jets are put in action by opening the water faucet, *h*, the charged air is gradually expelled through *b* as the water level in *A* rises. When an efficient jet is used the rate is usually about $dV/dt=2$ liters/minute. This velocity may be increased or diminished by aid of the flask, *M*, attached at *k*.

Since the jets from *j* impinge on the walls* of the vessel, this is kept uniformly moist, or better, coated with water and therefore continually put to earth by the hydrant connection. Similarly the pipe, *e*, leading to the outer coating of the condenser is with this continually put to earth. The core of the condenser, insulated by long hard rubber supports, *i*, *i*, retains charge well, even at high potentials and in spite of the damp gases, because of the remoteness of the supports.

3. *Results—Initial Charges.*—The following table gives the data obtained when the nuclei generated by the spray are *at once* passed into the tubular condenser, whose inner surface is charged as stated, the outer being put to earth.

TABLE I.—Ionization of water nuclei. $dV/dt = 2$ liters/min. Total capacity 72^{cm}. Deflections of electrometer *s* in the lapse of time given in the chart, curve No. 1.

Electrometer charge.	Insulation before.	a	Insulation after.	δs cm/min.
+ at	$a =$ ·013	·338	$a =$ ·010	7·9
20 volts		·490		7·1
— at		·072		3·2
20 volts	$a =$ —·020	·091	$a =$ ·002	3·8
		·108		4·0
		·124		4·0
+ at	$a =$ ·022	·223	$a =$ ·015	7·9
20 volts		·335		7·8
		·498		7·1
		·872		

Similar observations are given in the chart, curves 2 and 3, for higher potentials. The first observations are usually low, for the nuclei do not at once fill the condenser. The last observations are often high, § 14.

* Charged nuclei are also produced from jets impinging on a surface of water, without a solid obstacle, or when jets shatter each other. The efficiency, however, depends on the degree of comminution.

The method consisted in testing the insulation of the condenser, immediately before and after the introduction of water nuclei. The observations give the deflections, s, of the electrometer in cms. after intervals of 1 min., $\frac{1}{2}$ min., and 1 min., in each of the cases, respectively. The conduction, $a=\delta(\log s)/\delta t$, is computed by assuming Ohm's law; but in case of the medium of water nuclei, it is seen at once that Ohm's law does not apply, and that the conduction, a, increases enormously as the charge on the condenser vanishes. The average value of the conduction is quite of the order of values found for phosphorus nuclei elsewhere, under similar circumstances. As the data in the table show a for successive minutes, its variation in the last series is from ·223 to ·872 in 3 minutes.

Since $2{\cdot}3\ aC = 1/R$, where $C = 8/10^{11}$ farads, is the capacity of the condenser and appurtenances, the initial and final resistance, R, would be

$$R = 25\times10^{9} \text{ and } R = 6\times10^{9} \text{ ohms.}$$

It follows then that if the equation of the current be taken, or $i = n(U+V)e(E/l)$ in the usual notation, the number of nuclei, n, increases as the potential difference, E, diminishes. The same is true for the negative current with a smaller coefficient.

These and other results for the conduction, a, become more interesting if the electrometer deflections are charted graphically in relation to time as in the annexed figures 1, 2, 3. It is thus seen that the current is surprisingly constant, while the initial potential difference of about 20 or 40 volts gradually quite vanishes. In explanation, one may suppose that the number of ionized nuclei varies inversely as the potential difference, i. e., $nE=$ const.

It is apparently more simple, however, it seems to me, to assume that the velocity of the nuclei is independent of the potential gradient, each nucleus having its own specific velocity in the presence or the absence of an electric field, while the number of nuclei is practically constant,—the point of view taken in my earlier work.* The different currents for positive and negative charges in the condenser are then due to the known excess of negative nuclear charges. This view is actually *broader* (§§ 4, 14) than at first sight it seems, for it includes the case in which the velocity of the nucleus and the velocity of the ions or charges are the same function of the potential gradient in the condenser.

4. *Working Hypothesis and Constants.*—Supposing that the current is independent of the electromotive force of the condenser as just stated, and that k is the specific velocity of the nuclei (due to unsymmetrical bombardment, as heretofore

* Experiments with ionized air, l. c., chap. v, p. 69.

assumed), the radial current, di, at the element dl will be

$$di = 2\pi\,(r_2 + r_1)\,nke\,dl,$$

where r_2 and r_1 are the external and internal radii of the con-

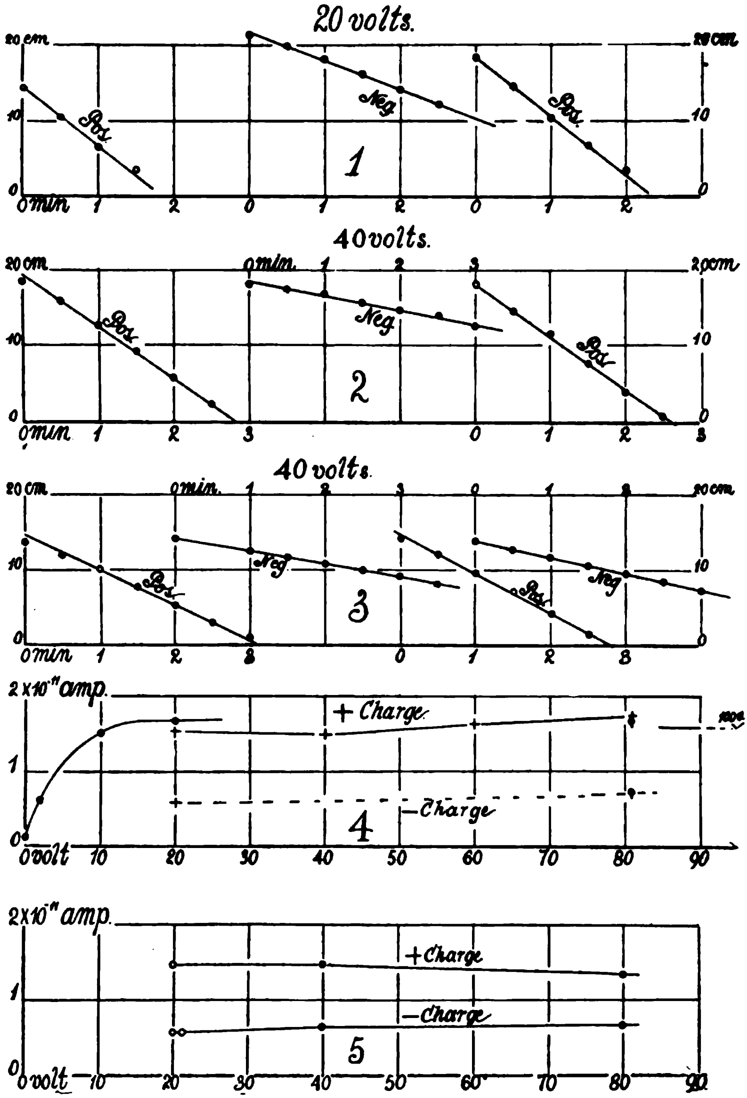


Chart 1.—Curves 1, 2, 3, electrometer deflection (leakage) after consecutive half minutes, for different charges and potentials in the condenser.

Curves 4, 5, radial currents (amperes) for different charges and potentials (volts) in the condenser.

denser of length, l, n the nucleation (number per cub. cm.), k their effective velocity and e the charge on each.

The value of n, for the case that decay of ions occurs merely by absorption of the charge at the walls of the cylinders, is $n = n_0 \epsilon^{-2kl/v(r_2 - r_1)}$ where v is the velocity (cm. / sec.) of the nuclei-laden air in the direction of the axis of the cylinder.

Here, however, a sharp distinction must be made between the fate of the nuclei and of their charges. The latter are absorbed, producing current. The water nuclei, so far as evidence from coronas goes, are not appreciably absorbed. With phosphorus the absorption of nuclei could be independently proven for the fresh emanation. It failed, however, for very wide tubes, implying stale emanation. Hence, after integration, if the leakage of the condenser is dE/dt and its capacity C,

$$C(dE/dt) = \pi evn_0 \,(r_2^2 - r_1^2)\,(1 - \epsilon^{-2kl/v(r_2 - r_1)}).$$

Since, $v = 16{\cdot}7\ V/\pi(r_2^2 - r_1^2)$, if V are the liters of nucleated air fed into the condenser per minute, the equation becomes,

$$dE/dt = \frac{16{\cdot}7\ n_0 e V}{C}(1 - \epsilon^{-{\cdot}377kl(r_2 + r_1)/V}). \qquad (1)$$

The length of the condenser enters only into the exponential quantity, and the results are the same if l/V is constant. Hence so long as the exponential quantity vanishes, k may be any function of the potential gradient, a result which gives the equation much broader significance than appears from the premises.

To find the value of the parenthesis, it may be tested by assuming $k = 1{\cdot}5$ cm. / sec., the value* for ionic velocities. Hence the constants are as follows:

$l = 50$ cm.	$V = 2$ liters / min.
$2r_2 = 2{\cdot}10$ cm.	$k = 1{\cdot}5$ cm / sec.
$2r_1 = {\cdot}64$ cm.	$e \doteq 2{\cdot}3 / 10^{19}$ coulombs,

and therefore the exponential quantity here vanishes. The equation now reduces to

$$dE/dt = 16{\cdot}7\ n_0 e V / C,$$

where n_0 is the initial number of nuclei entering the condenser, e the charge of each, V the liters of nucleated air supplied per minute, C the capacity of the condenser. The current is therefore independent of the length and radii of the condenser and the velocity of the nuclei. This will still be true of k in the two differential equations for di and dn above, is the same

* Experiments with ionized air, chapter iii. The value of k for water nuclei is much smaller than the datum assumed, as will be specified below.

function of the potential gradient $E/(r_2 - r_1)$; and so long as the value of k has not been directly found, the assumed small value of the exponential term is merely admitted for argument but will be further interpreted in § 14.

The additional constants needed are

$$C = 72{\cdot}5/9 \times 10^{11}$$
$$A = {\cdot}91, \text{ the voltage factor of the electrometer.}$$

The table then gives as the currents,

$$dE/dt = {\cdot}120 \text{ volts/sec., for the positive charge,}$$
$$= {\cdot}059 \quad \text{“} \quad \text{for the negative charge;}$$

so that the average current, ·090 volt/sec., may be taken as due to the ions, positive and negative, but neutral as a whole, while the observed values of dE/dt are due to the excess of negative ions. Hence

$$n_0 = \frac{(dE/dt)\ C}{16{\cdot}7\ e\ V} = 9{\cdot}7 \times 10^5$$

The number of ionized nuclei entering the condenser is thus estimated at about a million per cubic centimeter, if each nucleus carries one electron, and it will probably be indefinitely larger, if the nuclei-laden air-current V is swifter; for the charge is rapidly lost in the conveyance tube e between the receiver A and the condenser C, fig. 1.

5. *Comparison with Coronas.*—The number of ions thus computed is excessive, particularly in view of the number of nuclei obtained from the order of the first corona. The previous investigations show that this is number 9 in my series, and corresponds to about 5,000 nuclei.

Several inferences are thus suggested: either the charge of each nucleus is about 200 times larger than the value assumed, i. e., each nucleus on entering the condenser brings 200 electrons; or nuclei are lost at the outset at an enormously rapid rate, so that only ·005 of the original number remain when the first condensation is made; or finally, that each nucleus emits 200 electrons as a result of the peculiar radio-activity inferred by J. J. Thomson (l. c.). The second view may be disproved by direct tests. My own preferences in this paper are for the first, for the reasons to be given in the sequel.

6. *Potential of the Nucleus.*—Assuming the nuclei to be 10^{-6} cm in radius (they are probably smaller), their capacities will be $10^{-6}/9 \times 10^{11}$ farads. Hence the potential of each is

$$V = 4{\cdot}1 \text{ volts.}$$

With the particles present even to the extent of a million per cub. cm., this charge would be easily retained, since it

requires about 1,500 volts to spark across the intervening space of $\cdot 02^{cm}$. With only 5,000 or 6,000 particles present the condition would be enhanced over five times.

There seems then to be no reason for departing from the point of view in this paper even if the number of nuclei computed from coronas is somewhat low. As the nuclei neither vanish coincidently with the ions nor are present in similar orders of numbers, a sharp distinction must be drawn between nuclei and ions.

7. *Behavior of Phosphorus.*—It will be interesting to insert, by way of comparison, the corresponding treatment of phosphorus nuclei. The last equation for n cannot here be assumed, for Ohm's law is roughly obeyed. The conductions obtained above depend on the intensity of the ionizer, and on the air current, V, and the conduction $a = \cdot 3$, found elsewhere, may be assumed for $V = 2 \cdot 5$ liters/min., as an average case.

The current must here be written

$$di = 2\pi(r_2 + r_1)kne\frac{E}{(r_2 - r_1)}dl,$$

for the element, dl, while the number of nuclei, n, follows the same equation as above, if the spontaneous decay of nuclei in the lapse of time is ignored. The exponential term may again be omitted. The full result* after integration is

$$2 \cdot 3\, a = -(dE/dt)/E = -(ds/dt)/s = \frac{16 \cdot 7\, Ven_0}{(r_2 - r_1)\, C}(1 - \epsilon^{-.877\, kl(r_2 + r_1)/V}) \quad (2)$$

Hence,

$$n_0 = \frac{(r_2 - r_1)\, C\, 2 \cdot 3\, a}{16 \cdot 7\, Ve}$$

The constants are

$r_2 = 1 \cdot 05$, $r_1 = \cdot 32$, centim.,
$a = \cdot 3/60$, (referred to seconds)
$C = 8/10^{11}$ farads,
$e = 2 \cdot 3/10^{19}$ coulombs,
$V = 2 \cdot 5$ lit/min.

Thus

$$n_0 = \cdot 7 \times 10^5.$$

In my former work† with a condenser of totally different

* Experiments with ionized air, p. 67.

† Experiments with ionized air, p. 69; cf. pp. 53, 91, 93. Owing to an error in estimating the capacity of the electrometer, the results there given are too low and have since been corrected as in the text. This makes the phosphorus emanation richer in nuclei than air ionized by the X-rays, a condition otherwise probable.

dimensions ($r_2 = \cdot 60$, $r_1 = \cdot 32$, $l = 50^{cm}$) the result was $\cdot 6 \times 10^6$. The data for complete saturation were (after correction)* about 3×10^6, agreeing fairly well with the present cases where the ionization is necessarily undersaturated, because of the influx tube.

8. *Evanesence of the Charges of Water Nuclei.*—The same remarkable contrast between the initial charges and the subsequent charges on the nuclei will now be observed, if only a little time is allowed to intervene, that was already pointed out for phosphorus. Table 2 refers to nuclei produced in the receiver *A*, figure 1, by allowing the accumulating water to run off by the cock, *k*. They were then conveyed to the condenser *C*, about five or ten minutes later, by aid of the Mariotte flask, *M*. The conduction is enormously reduced, though for positive charges in the condenser it is greater than for negative charges, showing that an excess of negative nuclei has persisted.

Table II.—Ionization of water nuclei after 5–10 minutes. $dV/dt = 2{\cdot}5$ lit/min. Capacity 72^{cm}.

Charge.	Insulation before.	*a.*	Insulation after.	Corrected *a.*
+ at 30 volts	....	·019	$a =$ ·009	·010
— at 30 volts	....	·005	$a =$ —·002	·007

In Table 3 the data refer to nuclei which were left in the vessel *A* for about one hour after they were produced. The original ionization has all but vanished; nevertheless there is still an excess of negative nuclei, as shown by the greater leakage of positive charges in the condenser. If negative nuclei had been more rapidly precipitated in the intervening hour in *A*, the reverse should have been the case, there should have been an excess of positive nuclei, and negative charges in the condenser should vanish more rapidly.

Table III.—Ionization of water nuclei, 1 hour after production. $dV/dt = 2{\cdot}5$ lit/min.

Charge.	Insulation before.	*a.*	Insulation after.	Corrected *a.*
+ at 20 volts	....	·013	$a =$ ·009	.004
— at 20 volts	....	·003	$a =$ ·001	·002

Tested for coronas, after about one hour, 1,000–2,000 were left, or about 1/3 of the original 5,000, a result quite out of proportion with the loss of ionization. The electrical and condensational phenomena are thus again distinctly separated.

9. *Results with an Elliott Electrometer.*—For reasons which need not be stated here, the electrometer of modern type above, in which the charge is imparted to the needle through the suspension, notwithstanding its sensitiveness and low capacity, is not adapted for further experiments. Accordingly the data of the following table were obtained with an ordinary electrometer, with the quadrants permanently charged with a water battery. The core of the tubular condenser communicated with the needle. This adjustment was chosen because the leakage here was relatively smaller, though the high capacity of needle, jar and condenser is unfavorable to sensitiveness. The table contains results in which the potential of the core of the condenser was altered in steps of one half. Care was taken to determine the insulation immediately before and after each measurement with the nucleated medium. The leakage was always greater at the beginning than at the end, which is the usual phenomenon of absorption and release of charge in the insulators. If any trace of radio-activity occurred, it would be obscured by this phenomenon.

The results of these observations may be summarized as follows:

TABLE IV.—Charges of water nuclei. $dV/dt = 2$ lit/min. Capacity 409^{cm}. Deflection of the electrometer, s.

Electrometer charge.	Leakage ds/dt per 2^m Before. cm.	During nucleation. cm.	After. cm.	Current $C(dE/dt) \times 10^{11}$. amperes.	$n_0 \times 10^{-6}$.
+ at 81 volts	·13	·64	·09	1·33	1·72
— at 81 volts	·17	·39	·06	·67	·87
+ at 40 volts	·10	·67	·06	1·47	1·91
— at 40 volts	·11	·34	·05	·64	·84
+ at 20 volts	·08	·63	·03	1·45	1·89
— at 20 volts	·06	.27	·02	·57	·74

From these, since $n_0 = (dE/dt)\ C/16{\cdot}7\ e\ V$, the results of the last column follow, giving for the mean currents

at 81 volts $n_0 = 1{\cdot}3 \times 10^6$
at 40 $\quad 1{\cdot}4$
at 20 $\quad 1{\cdot}3$

These values of n_0 are somewhat greater than the preceding ($n_0 = 10^6$), but the difference is at once referable to the gradually increasing size of the holes in the lead jet as the result of long spraying. Slight changes in V lit./min. are now of importance because of the rapid loss of the charges in the influx tube of the condenser.

Whereas the current for positive charges decreases with the potential, the current for negative charges increases; but this, too, is due to incidental reasons of the kind mentioned. Seen in the light of the results preceding and following it, the general evidence of the table is rather to the effect that the current in the condenser is constant, independent of the electromotive force when the gradient exceeds about 20 volts per radial centimeter.

These results are marked 5 in the chart.

10. *Further data.*—A series of results quite similar to the last but with a more sensitive electrometer, is given in the next table. As a rule positive charges were taken in succession, though a number of incidental data accompany the table. The insulation of the electrometer was found before and after each of the measurements with nuclei. Having been taken on different days and not in a single sweep, the results cannot be quite coincident, because of jet differences, water pressures, etc., as already stated.

These observations may be summarized as follows:

TABLE V.—Charges of water nuclei. $dV/dt = 2$ lit/min. Capacity 409^{cm}.

Electrometer charge.	Electrometer deflections, s. Leakage ds/dt per 2^{min}. Before cm.	During nucleation. cm.	After cm.	$C(dE/dt)$ $\times 10^{11}$ amperes.	n_0 $\times 10^{-6}$.
+ at 81 volts	·21	1·88	·17	2·17	2·2
— at 80 volts	·23	·98	·19	·95	1·0
+ at 81 volts	—	1·98	·22	1·74	2·3
+ at 60 volts	·22	1·79	·13	1·62	2·1
+ at 40 volts	·11	1·55	·04	1·48	1·9
+ at 20 volts	·05	1·57	·00	1·54	2·0
— at 20 volts	·13	·68	·05	·59	·8
+ at 20 volts	·08	1·56	·02	1·51	2·0
+ at 20 volts	·08	1·46	·05	1·66	2·2
+ at 10 volts	·02	1·29	·00	1·51	2·0
+ at 2 volts	·01	·52	·00	·61	·8
± no charge	·00	·11	·00	·13	·2
+ at 100 volts	·16*	·88	·12	1·59	2·0

Corona on immediate condensation: white, crimson, green, being No. 9 with 5000–6000 nuclei per cm³.

* Smaller electrometer factor.

The currents are given in the chart and marked 4. They show that above 10 volts the currents are practically constant, remembering that any change in V due to water pressure, etc., will convey the nuclei more rapidly into the condenser, and from their exceedingly rapid decay at the outset, the currents will necessarily be variable. Below 10 volts the current decreases with the potential but remains quite appreciable even when the potential is zero with the absence of charge in the condenser. The two observations made for the negative charge indicate similar relations, when taken in connection with the preceding results.

The average number of nuclei in those cases where positive and negative charges were observed are found to be

$$\text{at 81 volts} \quad n_0 = 1{\cdot}4 \times 10^6$$
$$\text{at 20 volts} \quad n_0 = 1{\cdot}6 \times 10^6$$

results slightly larger than the preceding, again due to further enlargement of the holes of the jet, whereby fresher nuclei are put into the condenser.

The table states that the most advanced corona obtainable did not exceed No. 8 or 9 of my series,* throughout the whole of the work. It makes little difference whether the corona is taken instantly or a few minutes after the jet is shut off. The number of nuclei, therefore, is constant throughout the experiments.

Summary and inferences.

11. *Charge and Conduction.*—The data have shown that positive as well as negative charges are dissipated by water nuclei, immediately after they have been produced, and that the ionization, if it may be so called, is quite of the order of that of phosphorus. After being stored but a few minutes, the nucleation loses all but a few per cent of this property of conduction, behaving in this respect again like phosphorus nuclei. The number of nuclei does not appreciably vary in the same time. The character of the ionization (whether positive or negative nuclei are in excess) remains intact, so long as it can be observed. Hence the large initial and the eventual very small conduction (a few per cent of the original value) may be regarded as two successive phases of a single continuous phenomenon, either of charge or ionization or conduction. It seems to me therefore that it is not necessary to distinguish the initial charges from the initial ionization. The experiment as a whole shows an *attenuation of the Lenard effect*, continuously, through infinite time. One is at liberty to refer the conduction either to charged nuclei or to ionized nuclei, unless some

* Phil. Mag. (6), iii, p. 80–91, 1902.

distinctive definition is adopted. Both occurrences are similarly reduced. The present case of river water is one in which there is an excess of negative over positive nuclei. In other cases (pure water) the reverse may be the case, or again there may be an absence of an excess of either sign. If the nuclei were without charges, however, the medium would not conduct (§ 14). In a condenser positive or negative charges are soonest dissipated according as there is excess of negative or positive nuclei in the medium, respectively.

12. *Number of Electrons.*—Assuming each nucleus to have its own specific velocity, independent of the potential gradient of the electric field, and to carry one electron, the number of nuclei per cub. cm. was preliminarily computed as $n_0 = C\,(dE/dt) = /16{\cdot}7\ e\,V$, where C is the capacity, dE/dt the leakage of the condenser and appurtenances in practical units, e the charge in coulombs on each, and V the volume of nucleated air, in liters, entering the condenser per minute. Attributing the larger current from positive charges in the condenser to an excess of negative ions, the average current was assumed to represent the case of an equal number of ions of either sign, i. e., when the excess of negative ions has been removed. The values so obtained for this average current if each nucleus carries but one electron (which cannot be the case) are

$$
\begin{aligned}
n_0 = {} & 1{\cdot}0 \times 10^6 \\
& 1{\cdot}3 \\
& 1{\cdot}5
\end{aligned}
$$

The increase is due to the gradual wear of the jet, whereby fresher nuclei are conveyed into the condenser, as explained.

13. *Number of Nuclei.*—With this large number of ions, the number of nuclei as estimated from the coronas is in sharp contrast. There being less than 10^4 and more than 10^3 original nuclei, the charge of each must be greater than 100 and less than 200 electrons, agreeing that the whole charge is carried by the nuclei, for which there is good reason as the currents and the number of nuclei increase together with the efficiency of the jet.

If each nucleus is to carry the charge stated, its potential will still be of relatively small value, as was shown in § 6.

14. *Ohm's Law.*—For potential differences above 10–20 volts or gradients of 15–30 volt/cm., the currents in the condenser are roughly constant. Below this the current begins to decrease with the gradient, without, however, quite vanishing, even when the potential difference is zero. In the above tables, or chart No. 4, for instance, the average current for a charge at

10 volts, gave $n_0 = \cdot 9 \times 10^6$
2 $\cdot 5$
0 (negative only) $\cdot 2$

J. J. Thomson (l. c.) accounts for these phenomena by a bold and original hypothesis that each nucleus is superficially polarized with positive oxygen and that negative corpuscles are, as a consequence, projected from it into the medium. A constant current independent of the electromotive force results when as many corpuscles are produced per second as are consumed by the current.

To me it seems, however, that the hypothesis of this paper points to a simpler explanation.

In the first place the equations used in the case of water nuclei

$$dE/dt = \frac{16\cdot 7\ n_0 e V}{C}(1 - \epsilon^{-\cdot 377 kl(r_2+r_1)/V}) \;.\;.\; (1)$$

and in case of phosphorus nuclei,

$$(dE/dt)/E = \frac{16\cdot 7\ n_0 e V}{C(r_2 - r_1)}(1 - \epsilon^{-\cdot 377 kl(r_2+r_1)/V}) \frac{U}{k} \;.\;.\; (2)$$

contain an exponential factor, which is increasingly more important when k is small. Furthermore in equation (1), k cancels out in the coefficient of the parenthesis, and may therefore be any function of the potential gradient within the condenser. Equation (1) is thus true, no matter whether k is a function of $E/(r_2 - r_1)$ or not, and an equation involving both (1) and (2) may be written, if $(1 - \epsilon^{-a})$ stands for the exponential factor,

$$dE/dt = \frac{16\cdot 7\ n_0 e V}{C} \frac{1}{1 + k/(UE/(r_2 - r_1))} (1 - \epsilon^{-a}) \;.\;.\; (3)$$

where U is the combined velocity of the ions or charges in the unit electric field, and k is the effective velocity of the nuclei. In other words, k is now replaced by $k + UE/(r_2 - r_1)$.

Hence if the value of k is large as compared with $UE/(r_2 - r_1)$, i. e., if the nuclei have a specific velocity large in comparison with the ionic increment due to the field, that is if the nuclei are very small, equation (2) may be assumed, as was done for phosphorus nuclei.

If the value of k is small as compared with $UE/(r_2 - r_1)$, i. e., if the nuclei are relatively large, then equation (1) is approached, as was found to be the case for water nuclei. The full value of the exponential term is

$$1 - \epsilon^{-\cdot 377 (r_2 + r_1)(k + UE/(r_2 - r_1)) l/V},$$

and from the small value of k under consideration, it depends

essentially on E. Hence if the ionization is neutral (equality of positive and negative ionization or charge), the current will vanish with the potential gradient or with the charge in the condenser.

It is next in place to show that the exponential factor soon becomes constant and equal to one. This is done in the following table by direct computation, using the constants already summarized.

$k+UE/(r_2-r_1)=$	·001 cm./sec.	$1-\epsilon^{-a}=$	·013
	·010		·121
	·100		·736
	1·000		1·000

Hence when the total nuclear velocity approaches the usual values of ionic velocity in air (1·5 cm./sec.), the current is constant and

$$dE/dt = 16{\cdot}7\ n_0\, e\, V/C.$$

Thus the character of the curve given in the chart is actually predicted without an assumption as to radio-activity.

It is further pointed out by the equation that uncharged water nuclei cannot conduct appreciably, seeing that they owe their effective velocity to the field, which becomes inactive in the absence of charge.

Finally the velocity of the water nucleus under an assumed probable size may be computed. The resistance to motion at velocity v, of an infinitely small sphere of radius R in air of viscosity μ is $6\pi\mu Rv$ dynes (Kirchhoff's Mechanik, lecture 26, § 4). The pull of the field on the charge e is equal to this, whence

$$v = Ee/(6\,\pi\,\mu\,R\,(r_2-r_1)).$$

If the nuclei diffuse appreciably, R is smaller than 10^{-5} cm. which would follow for subsidence, and R may then be estimated at 10^{-6} cm.; while $\mu = 2\times10^{-4}$, $r_2-r_1 = {\cdot}73^{\mathrm{cm}}$, $E=20/300$ and $e = 200\times7\times10^{-10}$ electrostatic units, if each nucleus carries 200 electrons. Hence

$$v = 3{\cdot}4 \text{ cm./sec.}$$

which is about ·12 cm./sec. in the field of one volt/cm. This value is actually very large as compared with the values which I found (§ 15) for the velocities of water nuclei in the absence of a field, but it is naturally dependent on the uncertainty of R. I shall waive the subject here, as I propose to return to it more specifically elsewhere.

15. *Comparison of Phosphorus and Water Nuclei.*—Between phosphorus and water nuclei there is in the first place the

essential difference that whereas the current in the first case obeys Ohm's law, roughly, it does not do so in the second, being more and more independent of the electromotive force as E increases above about 15 volts per cm. Corresponding to this the coronas for water nuclei terminate with the ninth in my series (5000 nuclei, § 5), whereas in case of phosphorus they go to indefinitely higher orders beyond the first (3×10^6 nuclei) in the series. Parallel to this there runs a difference in the size of nuclei. The inference is warranted that phosphorus nuclei are small as compared with water nuclei, inasmuch as the latter owe their origin to mechanical conditions (evaporation from gross fog particles), while the phosphorus nuclei arise under chemical conditions and molecular dimensions.

Finally, in direct measurements made by the steam jet method (Experiments with Ionized Air, chap. iii), the velocity of the phosphorus nucleus in the absence of an electric field was actually shown to be of the order of ionic velocities in air, while with experiments* since made with water nuclei ·001 to ·01 cm. / sec. are average orders of values depending on the concentration of the solution. Experiments are in progress to determine the velocity, k, with the identical water nuclei under discussion in the above paragraphs; but the data in hand are sufficient to warrant the use made of the hypothesis.

In other respects there is great similarity in the behavior of the two types of nuclei. The enormous charges or ionizations at the beginning vanish to a residuum of a few per cent in a few minutes, if confined by a receptacle, while the nuclei are not affected either as to number or condensational properties by the presence or absence of the primitive charge.

16. *Condensational effect of Negative Ionization.*—In none of the experiments, either with the neutrally ionized phosphorus emanation (where the ionization was tested after partial condensation and subsidence of fog particles) nor with the negatively ionized solutional nuclei is there evidence that negative ions are more active as condensation nuclei than positive ions. The electrical conditions vanish to a few per-cent almost at once, while the nuclei are relatively permanent. Experiment makes it improbable that the small residuum of charge can have any appreciable bearing on condensation; witness the identical behavior of water nuclei when used immediately after production and highly charged, and when used some time later, after the charge has certainly left them. Moreover the charges vanish proportionately, which they would not do if the negative ions had a greater affinity for

* This Journal (4) xiv, p. 225, 1902; cf. forthcoming memoir on "The Structure of the Nucleus," Smithsonian Contributions, 1902.

water vapor. An initial excess of positive or negative ions means a corresponding excess in the small electrical residuum.

Regarding Wilson's famous experiment, I have already expressed my belief that it is the unavoidable synthesis in a region of intense ionization that furnishes the nucleus, and that such synthesis must be different on the acid and alkaline side of a battery.* The same explanation would apply to nuclei obtained from any kind of radiation.

17. *Induced-radio-activity.*—In none of the experiments was observable radio-activity imparted to the core of the condenser. The insulation determined before and after the passage of the nucleated medium showed greater leakage in the first than in the second instance, whether the charge was positive or negative. This corresponds to the usual electric absorption of insulators. If radio-activity had been present, the latter insulation should have been worse than the earlier, instead of the reverse case, invariably observed.

True the potentials did not exceed 100 volts and in J. J. Thomson's experiments a Wimshurst machine was needed to bring out the radio-active effect. But if within the limits of the above experiments no such effect was demonstrable, I do not see that one is at once at liberty to assume it; for it is quite possible that the enormous potentials of the electric machine introduce conditions which have no bearing on the work of the above pages. One may imagine, for instance, that a compound of metal and water nuclei may be stable in presence of a strong negative field, but unstable in the absence of the field, just as I suppose that a compound of oxygen and phosphorus is stable in presence of excess of phosphorus (close to the surface of the phosphorus) but unstable in excess of air (away from the phosphorus), and that the dissociation is accompanied by ionization. To this extent I have ventured on an independent explanation of the phenomena detailed, in keeping with my earlier work.

18. *Conclusion.*—A few general remarks may be added. Referred to a cubic kilometer the charges of the above nuclei would aggregate to about 200 coulombs, with an excess of negative charge as stated. If this region were spherical, with a superficial capacity, and if the charge of a given sign were transferred to the surface, its potential would be, in the average case, of the order of a thousand million volts. Finally the mobility of the nuclei is of the order of about eight-tenths of a mile in the unit electrostatic field, and the mere attrition of water by water is sufficient to generate them.

Brown University, Providence, R. I.

* Science, xvi, p. 633, 1902.

ART. X.—*The Morphogenesis of Platystrophia. A Study of the Evolution of a Paleozoic Brachiopod;* by EDGAR ROSCOE CUMINGS.

[Continued from p. 48.]

General Observations and Conclusions.

Platystrophia, as shown by its development and early history is descended from an ancestral *Orthis* having eight or nine plications on each valve, a ventral fold and dorsal sinus, and erect, high cardinal areas, with large open delthyria in each valve. Such a combination of characters is found in adult forms of the *Orthis lenticularis* group of the Upper Cambrian. The close resemblance of *Orthis lenticularis* to the nepionic shell of *Platystrophia*, together with its high variability and wide distribution, warrant the conclusion that it is the ancestor of the latter genus.

From this primitive stock was derived in the early Ordovician, a shell with a ventral sinus and dorsal fold; and with one plication in the sinus, two on the fold, and four to six on either side. In the early Trenton (or possibly before) this latter form underwent a differentiation into two species; one having fundamentally one plication in the median line of the sinus, representing the continuation of the median ventral fold of the nepionic stage, and an additional implanted plication on either side of this primary plication; the other having fundamentally two plications in the sinus arising by the bifurcation of the nepionic ventral fold. These species are *P. lynx* and *P. biforata*, respectively.

From *P. lynx* was derived in the Ordovician of America (*a*), by reduction of the secondary plications of fold and sinus, the variety *costata* of the lower Lorraine; (*b*), by elevation of the fold and extension of the cardinal angles, the variety *laticosta* of the Lorraine; and (*c*), by farther extension of the cardinal angles and addition of lateral plications, the species *acutilirata* of the Richmond; (*d*), by obsolescence of the secondary plications of fold and sinus in *laticosta*, was produced the form *unicostata* of the upper Lorraine. *P. lynx* attained its maximum development (acme), living in association with the above *varieties*, in the Lorraine of the Ohio Valley, and in the upper Lorraine passed through a series of gerontic modifications. A nearly normal form of *lynx* survived till the close of the Ordovician, making its appearance in great numbers in the extreme upper part (Madison beds) of that system. *P. acutilirata* passed through a series of retrogressive modifications in the upper Richmond, and became extinct at the close of the Ordovician. *P. costata*, by accentuation of the fold and sinus (bilobation), gave rise to the genus *Bilobites*, which survived till the early Devonian (Lower Helderberg).

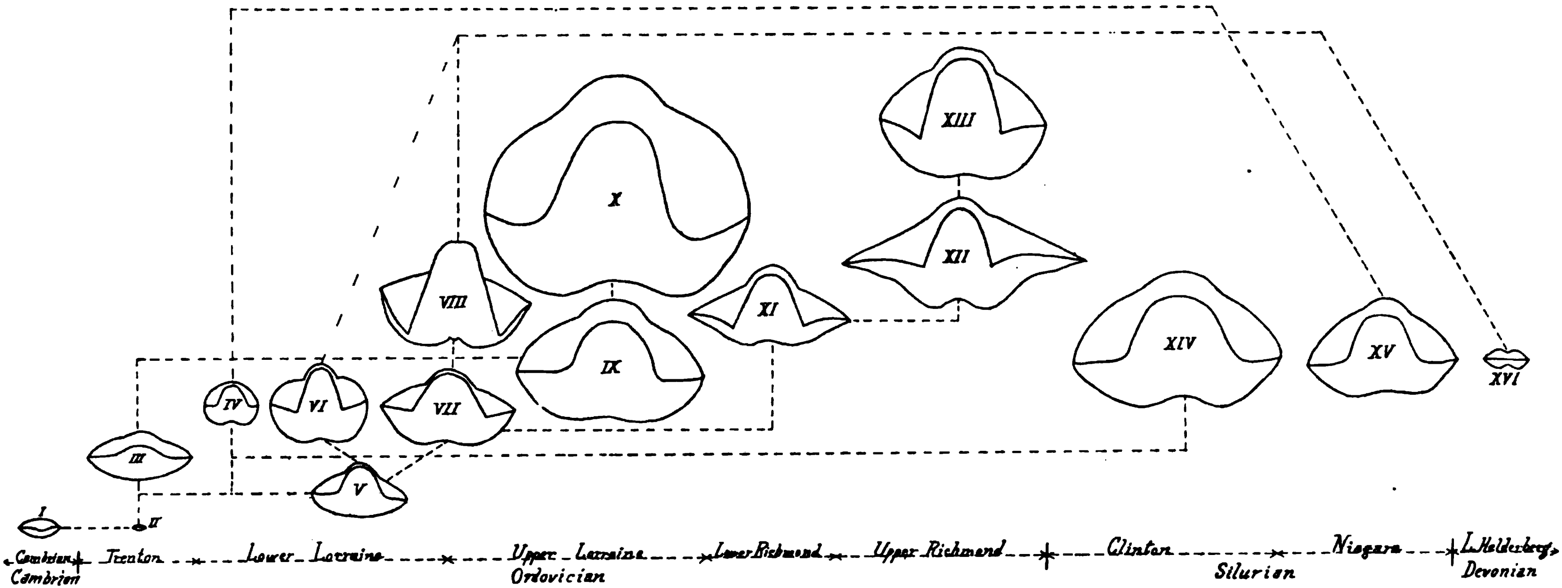


FIG. 26.—Diagram showing anterior views of the types of *Platystrophia* from the inception of the genus in the Trenton to its termination in the Niagara. I, *Orthis lenticularis* (corresponding to the nepionic *Platystrophia;* II, hypothetical early Ordovician representative of the group corresponding to the neanic growth stage of *Platystrophia;* III, normal Trenton *lynx* type; IV, *P. dentata*, derived from a primitive *biforata* type; V, lower Lorraine pauciplicate *lynx* type, from which were derived (VI) *P. costata* and (VII) *P. laticosta*, and from the later *P. unicostata* (VIII). From the Trenton *lynx* the Lorraine *lynx* (IX) descended directly and took on a gerontic modification (X) in the late Lorraine of the Ohio Valley. *P. laticosta* (VII) gave rise in early Richmond time to *P. acutilirata* (XI), and the latter, after becoming very *acuminate* (XII) in late Richmond time, assumed a regressive type (XIII). The Clinton form *P. biforata* (XIV) was derived in the early Ordovician of Europe from a primitive stock; and *P. dentata* of the Niagara (XV) represents the same stock as number IV. The latest member of the group, *Bilobites varicus* of the Lower Helderberg (XVI), was derived either from number VI or number VIII.

From the *biforata* stock were derived the Ordovician types *dentata* and *fissicostata*. Both *biforata* and *dentata* passed on into the Silurian, the former becoming extinct in the Clinton (in this country at least), and the latter in the Niagara, after assuming markedly primitive characters.*

The facts presented above are expressed diagrammatically on figs. 26 and 27. Fig. 26 shows anterior views of the forms of *Platystrophia*, characterizing the several geological divisions from the Cambrian to the Lower Devonian. One striking fact brought out by the diagram is the progressive increase in size (bulk) of the forms up to the culmination (acme) in the upper Lorraine; and the decrease in size from that point on. Another feature is the rapid multiplication of new forms in the Lorraine, and especially in the lower Lorraine. Another characteristic, which this diagram is especially designed to show, is the two types of sinus during the Ordovician: the angular (*VI*, *VII*, *VIII*, *XI*, *XII*, *XIII*), and the rounded (*III*, *IX*, *X*, *XIV*). These two types of sinus correspond to the two lines of descent, namely, from a pauciplicate and a multiplicate stock, respectively, as is shown in fig. 27. The Silurian forms find their nearest American Ordovician parallels, so far as this feature is concerned, in the *lynx* group. The European Ordovician forms, except *dentata*, are not shown on either fig. 26 or 27.

Fig. 27, in which the Roman numerals† correspond to those of fig. 26, is intended to express the ontogeny of each form as well as the phylogeny of the entire group. This figure shows several adult forms not shown in fig. 26. These are *Platystrophia lynx* of the upper Richmond (XVIII); *P. dentata* of the Niagara of the Mississippi Valley (XIX); *P. laticosta* of the lower Richmond (XI *a*); gerontic *P. costata* of the upper Lorraine (VI *a*); and *Bilobites verneuiliana* of the Clinton (Gotland). In this figure the forms below the horizontal lines, to which Arabic numerals are affixed, are ontogenetic stages of the forms above the horizontal lines, to which Roman numerals are affixed. It will be noted that the nepionic stage is the same for all except *Bilobites* (cf. 1–7 and 8–9). The neanic stage is the same for all the Ordovician forms (10–14), and has invariably one plication in the median line of

* There are several specific and varietal designations that have been applied to various forms of *Platystrophia*, which have not been mentioned above. These are *P. dorsata* Hisinger sp. (Leth. Suec., 1837, p. 76); and *P. tridens* and *P. terebratuliformis* McCoy sp. (Syn. Sil. Foss., Ireland, 1846, pp. 37, 38). Of *P. dorsata* deVerneuil says: "The *Atrypa dorsata* which we place in the synonomy of this species [*P. biforata*] has the plications more numerous, and might be considered as a variety of it." I have seen no specimens of this form, but probably deVerneuil's disposition of it is correct. *P. tridens* McCoy, as shown by his figures, is a typical *P. dentata*; and *P. terebratuliformis* is evidently a *P. fissicostata*, i. e., it belongs to the *biforata* group.

† Except *IV*, which is a pauciplicate *P. lynx*, the homœomorph of *P. dentata*.

the sinus and the beginning of another plication on either side (i. e., the type is fundamentally triplicate). The neanic stage of the Silurian forms (15, 16) has two plications in the sinus, arising by bifurcation of the median plication of the nepionic stage (i. e., the type is fundamentally biplicate). The early ephebic stages of upper Ordovician forms correspond closely to fully adult stages of lower and middle Ordovician forms (cf. 19 and 20 with III and IX; 22 with VI; 23, 24 and 25 with VII).

Distribution of Platystrophia.—On the map of the Northern Hemisphere (fig. 24) is shown the distribution of *Platystrophia.** Most of these localities have already been mentioned. Those which have been added through recent investigations may be mentioned briefly.

Platystrophia biforata (?) has been reported from Baffin Land by Schuchert.† The specimens are said to be small and narrow at the hinge. Whiteaves cites the same species from Akpatok Island, on the south side of Hudson Strait.‡

Recently *P. biforata* has been collected from the mainland near Nova Zembla (Khabarova) by the Swedish North Polar Expedition under Nansen.§ Johan Kiær, in a recent paper, reports *P. biforata* from near Christiania, Norway.‖ Weller reports *P. lynx* from New Jersey, from a horizon low in the Trenton.¶ White found the species in New Mexico at Silver City.** Professor H. S. Williams has a specimen of *P. lynx* from Arkansas.

It will be noticed that the genus has never been found in the Southern Hemisphere, nor in any region adjacent to the Pacific Ocean. Nevertheless the area of its known distribution represents nearly forty degrees of latitude and one hundred and seventy degrees of longitude.

We should not be too hasty in drawing conclusions from the above facts of distribution, in regard to questions of correlation and Paleozoic geography; nevertheless several points seem to me, if not demonstrated, at least forcibly suggested.

The biplicate type of *Platystrophia*, so characteristic of the European Ordovician, is absolutely wanting in the American Ordovician outside of the Hudson-Champlain trough. This

* This map is based on a stereographic projection upon the plane of the Equator, prepared by Professor S. L. Penfield. (See this Journal, vol. xiii, May, 1902, p. 252.) The amount of distortion within the 40° of latitude is slight.

† Proc. U. S. National Museum, xxii, 1900, pp. 151, 158.

‡ This Journal (4), vii, 1899, pp. 433, 434.

§ Johan Kiær, Sci. Res. N. Polar Expd., vol. iv, xii, 1902, p. 7.

‖ Separataftryk af Norges Geologiske Undersogelses Aarbog for 1902, p. 61

¶ Kümmel and Weller, Bull. Geol. Soc. Amer., 12, 1901, p. 158.

** Geol. Expl. West of the 100th Meridian, 1874, iv, p. 74.

indicates, as pointed out by Ulrich and Schuchert,* a connection of this latter area with Europe during the early Ordovician, and its separation from the Mississippi area. I believe also that the strong similarity of *P. biforata* of the Champlain trough to the European lower Ordovician forms indicates close contemporaneity of the two terranes.

Again, the Clinton *Platystrophia* of this country is almost identical with the European *P. biforata*, and therefore indicates a migration of European forms into American waters of the Mississippi area at the close of the Ordovician. This also coincides with the views of the authors just mentioned. The Niagara species, *P. dentata*, is identical with the Gotland form, and differs from the Clinton form, thus indicating a second migration of European forms during Niagara time. The bearing of this evidence upon Dr. Weller's views has been pointed out in another place.

A point perhaps worth calling attention to, is the erroneous ideas current in regard to the distances to be covered by these migrating forms and the routes pursued, that we obtain from Mercator projections and globular and stereographic projections on any plane but that of the Equator. By reference to the map, fig. 24, it is clear that the route of a form migrating from Gotland, for example, into the Mississippi Valley, is no more circuitous by way of Hudson Bay than by way of the Atlantic. It is even less so.

Laws of the Evolution of Platystrophia.—It is not to be assumed that the history of *Platystrophia* outlined in the preceding pages is in any way complete, or that it could ever be made complete by any amount of research. Every worker in this department of science is painfully aware, when he appeals to the original sources of information, the rock-strata, of the many volumes of the record irretrievably lost, and of the many events never recorded at all. My aim has been to have before me specimens of all the forms of *Platystrophia* known from American terranes; and this has been rendered possible through the kindness of the gentlemen mentioned above, to whom I once more express my gratitude. I should have been glad, indeed, to have had the same opportunity of examining all the European forms; but for the present this is impracticable. Imperfect access to available material is, therefore, added to the imperfections of the original sources of information. What, therefore, rests on theory the reviewer must accept or reject according to his convictions of its merits or demerits. The facts, many of which I have had the pleasure of ascertaining and many of which are due to the labors of others, I have endeavored to present in such a way that the risk of confusing them with theory will be avoided.

* Bull. N. Y. State Mus., No. 52, 1902, pp. 633–663.

The observations which follow assume that the history of *Platystrophia*, outlined above, is in the main correct; and have suggested themselves from time to time as the investigation proceeded.

Variability.—*Platystrophia* presents its highest degree of variability near the beginning (epacme) of its history, and thenceforward becomes progressively less variable, till finally only characters of no physiological importance are affected. In other words, *variability is progressively restricted to characters of lower and lower taxonomic value.**

Considering the entire group, the presence of a ventral sinus is a generic character from the early Ordovician on; but the ancestral form, *Orthis lenticularis*, has the sinus in the *dorsal* valve (as in the nepionic shell of *Platystrophia*), so that at some time between the Cambrian and Trenton the type varied in this respect. Since, moreover, the fold and sinus of Brachiopods are undoubtedly due to the presence and position of the brachia, such a transfer of the sinus from one valve to the other indicates a considerable readjustment of the internal organs, and of the brachia in particular.

In all forms of *Platystrophia* above the basal Trenton, the sinus is either definitely biplicate or definitely triplicate; and this character delimits the primitive species *biforata* and *lynx*. In the early Trenton, however, we meet with both biplicate and triplicate shells associated together, and the inference is that at that time the mode of origin of the plications of the fold and sinus was variable. In the lower Lorraine the pauciplicate *P. lynx* has indifferently one, two, or three plications in the sinus; but a little later these peculiarities tend to become fixed in distinct types, so that ultimately *laticosta*, and especially its derivative *acutilirata*, have almost constantly three plications in the sinus, while *Bilobites* derived from *costata* has the single median plication of the latter fixed as a persistent nepionic character which is absolutely invariable. Throughout the Trenton and Lorraine *P. lynx* varies extensively in contour and number of plications, the limits being between six and twelve plications on each side of the fold and sinus, and the average seven on each side. In the late Richmond, where *lynx* reappears in great numbers, it has almost constantly between nine and twelve plications on each side of the fold and sinus, and the shell index is uniformly high. The sinus index, which seems to have no fixity at all in Lorraine forms, is in *acutilirata* fairly constant. The early forms of the *P. biforata* group, according to European authors, vary extensively in contour and number of plications, and this variability is still high, especially the number of plications, in our Clinton forms; but

* Cf. Hyatt, Proc. Bos. Soc. Nat. Hist., xxxii, 1895, p. 371.

the *P. dentata* of the Niagara is almost absolutely invariable in these respects.*

A corollary of the law of progressive restriction of variability is the *rapid production of new types near the beginning (during the epacme) of a phylum.*† Thus the two primitive species *biforata* and *lynx* were produced in the early Ordovician; *laticosta*, *costata*, and *dentata*, in the Trenton-Lorraine; *unicostata* in the upper Lorraine, and *acutilirata* in the Richmond. The entire Silurian furnishes not a single additional type. *Bilobites*, the only genus derived from *Platystrophia*, originated some time during the Ordovician. *The notion that species are formed by very gradual increment of selected variations certainly does not suit the present case.* Many of the earliest individuals of *P. lynx* and *P. biforata* are as typical of those species as any that occur subsequently. So many early specimens of *P. laticosta* and *P. costata* are typical representatives of their respective lines. *The fundamental difference between the early and later history of these types is the presence of intermediate groups during the former period and their absence during the latter.*‡

It is possible that species may originate within a single generation. This is even insisted on by De Vries.§ It certainly has occurred among domestic races, as Darwin‖ himself points out, though systematists seem loth to admit that anything is a species the origin of which is a matter of historical record! Cope¶ has suggested the sudden origin of genera through the law of acceleration. Bailey,** in a very suggestive chapter on experimental evolution, shows that many species of plants originate suddenly under cultivation. I do not wish to be understood as maintaining that species habitually originate after this fashion; but cases such as that of *Platystrophia* (and many similar ones will occur to the mind of every paleon-

* Shaler's name, *regularis*, applied to the Anticosti form of this species, probably alludes to this fact of invariability.

† On this subject see Hyatt, Proc. Bos. Soc. Nat. Hist., xxxii, p. 371.—Williams, Geological Biology, pp. 321, 322.—The fact has been noted by many other paleontologists: Schuchert, Beecher, Hall, Clarke, Walcott, Gratacap, etc.

‡ Prof. H. S. Williams has shown that the Silurian-Devonian type *Atrypa reticularis* affords a remarkable illustration of this law. (Geological Biology, pp. 315–322.) The Devonian *Spirifers*, on the other hand, seem to be a group in which segregation of species was more rapid, although *S. mucronatus* and *S. disjunctus* (Gosselet, Extrait des Mem. de la Soc. Géol. du Nord, iv, i, 1894) were certainly protean. A comparison of Hall's plates of *Spirifer* (Pal. N. Y., vol. iv) with our fig. 27 shows that the latter presents material enough for a dozen species, but for the connecting forms.

§ Origin of species by mutation, Science, N. S., xv, No. 384, May, 1902.

‖ Animals and Plants under Domestication, 1868.

¶ Origin of the Fittest, 1886, p. 79.

** Survival of the Unlike, 1896, pp. 107-137.

tologist) certainly point to the conclusion that *given a new and vigorous stock in a favorable environment, the initiation of new species takes place with great rapidity.* It does not matter whether the new stock has been derived by migration from some outside region or as an offshoot of an endemic stock, so long as its physiological peculiarities, or physical isolation, remove it sufficiently from competition with other stocks.*

After the initiation of new types, their segregation from each other into definite groups (species) was relatively slow. Intermediate forms persisted for some time. Segregation was not accomplished until most of the characters of the types had become fixed.

Intrinsic evolution.—Certain phenomena of the evolution of *Platystrophia* find their explanation in the progressive development or accentuation of characters of high physiological importance along the same line in different members of the genus, especially during its epacme. These are the phenomena of *morphological equivalence*† and *homœomorphy*,‡ of both of which *Platystrophia* affords excellent examples.

By morphological equivalence is meant the occurrence of similar forms in similar succession under like conditions of environment; and by homœomorphy, similarity of species in general features with dissimilarity in details. *P. lynx* and *P. biforata* present examples of both. These two species are perfectly distinct; nevertheless, the fact that the early representatives of *P. lynx* in this country have been persistently referred to *P. biforata*, while the later Russian Ordovician representatives of *P. biforata* have been as persistently referred to *P. lynx*, is good evidence of the parallelism of the two; and the similarity of the sediments in which they occur and of the faunas with which they are associated, is evidence of the similarity of environmental conditions. Both species run through a similar series of changes. Since they were derived from the same radical they were of course alike at the outset. In the middle Ordovician of Russia (see fig. 6 ante) we have a form which in size, gibbosity, incurvature of the beaks, number of plications, shell index, and cardinal angle is the homœ-

* Thus *Platystrophia* was a highly anomalous type of Orthid, a fact which gave it a distinct advantage. A factor that may have played an important part in the rapid evolution of new types, since it furnishes precisely the favorable conditions of physical environment demanded, has been pointed out by Prof. T. C. Chamberlin (Jour. Geol., vi, 1898, pp. 600-604). This is the extension of submarine shelves and epicontinental seas during periods of base-leveling and transgression. Such conditions existed, according to Chamberlin, in the middle Ordovician, the very time when *Platystrophia* attained its greatest expansion. See also Beecher, this Journal, vi, 1898, pp. 182, 183.

† Hyatt, Genesis of the Arietidæ, Mem. Mus. Comp. Zool., xvi, No. 3, 1889, p. viii.

‡ Buckman, Homœomorphy among Jurassic Brachiopoda, Proc. Cottes-wold Nat. Field Club, xiii, 4, 1901, pp. 231, *et seq.*

omorph of *P. lynx* of the upper Lorraine of this country: *but it is specifically distinct.* Again in the upper Richmond of this country is a form of *P. lynx* similar in almost every respect to *P. biforata* of the upper Ordovician and Clinton; *yet again specifically distinct.* The parallelism of the two series *lynx* and *biforata* is complete. Examples of homœomorphy besides those just mentioned, are *P. dentata* and *P. lynx pauciplicata*, biplicate form,—almost precisely alike in the adult, but differing in the early stages (neanic): *P. costata* and *P. laticosta unicostata*,—alike in number of plications and plication of the fold and sinus but differing slightly in cardinal angle, depth of sinus, and shell index, and very differently derived: the gerontic *P. acutilirata* and the upper Richmond *P. lynx*, differing only in early ephebic stages.

The relations of these homœomorphic forms are indeed suggestive. The feature that infallibly distinguishes the *P. lynx* and *P. biforata* groups is the mode of origin of the plications of the sinus and fold. Aside from this one character, however, the evolution of the two groups seems to have been determined by the same set of intrinsic characters which responded to the two sets of environmental conditions by similar reactions. These intrinsic characters centered in the progressively increasing development of the brachia. It was stated above that the shifting of the sinus from the dorsal valve (in *Orthis lenticularis*) to the ventral valve (in *Platystrophia*) was due to the increasing development of the brachia. The grounds for this statement are, the plan of symmetry of the shell which is undoubtedly primarily determined by the brachia, and the pretty general restriction of the sinus to the ventral valve. In those brachiopods (*Spiriferacea*, *Terebratulacea**) in which the extent of the brachia is definitely indicated by their calcified supports, the connection between the brachia and the sinus is obvious enough, and the development of the sinus is usually directly related to the extent and position of the brachia. In inarticulate brachiopods (*Atremata*, *Neotremata*) where there is more freedom of motion of the valves upon each other, a fold and sinus are seldom developed, for obvious reasons.

As there are no representatives of the *Orthidæ* extant, the condition of the brachia in that group can only be inferred

* In the *Terebratulacea* the sinus is more often in the dorsal valve than is the case in any other group. A glance at the brachia of such a shell will show that this is in reality the exception that proves the rule, for here the median lobe of the brachia extends toward the ventral mantle so that the real hiatus between the right and left lobes of the brachia comes on the side toward the brachial valve. This is beautifully shown in the figure of *Terebratulina coreanica* (fig. 13, plate 46) in Morse's recent splendid memoir on living brachiopods (Mem. Bos. Soc. Nat. Hist., v, 1902). Compare with *Spirifer striatus*, fig. 576 A, Zittel's Text book of Paleontology (Eastman Tr.), p. 336.

from indirect evidence.* *Davidsonia* of the Devonian has strongly impressed spiral markings in the interior of the ventral valve, indicating coiled brachia of several turns. In *Leptæna* similar evidence indicates still fewer turns to the brachia.† *Rafinesquina Jukesi*‡ shows similar impressions of one or two whorls in the spires. Quite similar impressions are sometimes seen in *Productus*.§ Among the *Orthidæ* there is no such direct evidence of the position and extent of the brachia; but it cannot be supposed that they differed materially in the *Strophomenidæ* and primitive *Orthidæ*. In both cases the brachia consisted of low spires of few turns with their axes approximately at right angles to the plane of separation of the valves. In *Platystrophia*, on the other hand, the strong tendency toward a profound sinus, together with the great extension of the cardinal angles, and general large size and robustness of the shell, indicate that the brachia were well developed and that probably the axes of the spires lay in the transverse diameter of the shell. The striking difference between *Platystrophia* and all the other *Orthidæ* may very well have been due primarily to this peculiarity. If the modifications of the sinus are correlated with modifications of the brachia, this view is certainly well founded, for the main lines of evolution of this genus are as a matter of fact marked out by modifications affecting the sinus.‖ If, further, the modification of the brachia was progressive and affected the entire genus, we have a perfectly adequate reason for the parallel evolution of the *lynx* and *biforata* groups, and an explanation of the homœomorphic forms mentioned above. Thus a wide separation of the two lobes of the brachia would account for the profound sinus and obsolescence of the lateral plications of the sinus in *P. costata* and *P. laticosta unicostata* and for the ultimate bilobation of the shell in *Bilobites*. The force of this will be seen at once if we compare such a form as *Spirifer mucronatus* (which *Platystrophia* so closely resembles) in which the sinus is deep, with *Meristina* in which it is shallow or lacking. In the former the bases of the spires are widely

* *Thecidium*, the only survivor of the *Strophomenacea*, has a rather feeble development of the brachia. Since, however, we are led to believe that this is a degenerate type, no safe conclusions in regard to the morphology of the brachia of ancient *Strophomenacea* can be based upon it.

† Davidson, Sil. Brachiopoda, 1869, pl. xxxix, fig. 16.

‡ Ibid. pl. xxxvii, figs. 25, 26.

§ *P. giganteus*, Zittel, Textbook of Paleontology (Eastman Tr.), p. 318, fig. 532 B.

‖ It may, of course, be argued that external factors caused changes in the depth of the sinus and that these changes caused readjustments of the brachia. This is gratuitous assumption. There is absolutely no reason why the mantle of a Brachiopod should sag in this particular region except that at this point it lacks the support of any internal structure. The development of a sinus under such conditions is a mechanical necessity.

separated; in the latter they are closely approximated. In the same way we may compare *Pentagonia* and *Meristella*.

The extent of the brachia may also bear some definite relation to the width of the shell.* Thus it might be reasonably expected that in such a form as *P. acutilirata* the spires would have a greater number of volutious than in such a form as *P. costata*. The analogy of the *Spirifers* holds here also; for in *S. mucronatus* there are often just as many turns to the spirals as plications on the shell. The *Spiriferacea* indeed suggest that there may be a more or less definite correlation between the presence and number of plications and the extent and position of the spires of the brachia.

The subject of the cause of plications is an exceedingly tempting one, but leads too far afield into the realm of theory to warrant extended discussion here. A few suggestions may nevertheless be hazarded.

The relation of the brachia to the mantle in structure and function is intimate, since the former are derived from the latter, and both coöperate in the function of respiration.† Some definite relation between the volumes of the two is, therefore, to be expected. Increase in the extent of the brachia is accomplished by folding and coiling of various sorts, while increase in mantle area is accomplished by radial growth (increase in the absolute size of the shell) and much more effectively by plication. The coöperative efficiency of the brachia and mantle can, therefore, for a shell of given size, be greatly increased by coiling or folding of the brachia and plication of the mantle. The correlation may be even more precise: for where the axes of the spires lie in the transverse diameter of the shell the position and direction of the successive volutions is such that the mantle may conform to them in shape, folding up and down as it crosses each turn.

There are other factors that may have been concerned in causing or accentuating shell plication. The greatly increased length of the mantle border of a plicated shell as compared with a smooth shell of the same size, is obvious. Such a plicated shell could admit the respiratory and food-bearing currents of water, and at the same time keep out foreign particles and disagreeable visitors, because the greatly lengthened slit between the mantle margins would not necessitate so wide a gaping of the valves of the shell. That there actually is a correlation between the gape of the valves and the presence of

* Beecher has pointed out the effect of mechanical restraint in the production of transverse shells (this Journal, vi, 1898, p. 337). Doubtless this factor was concerned in the great extension of the cardinal angles of *P. acutilirata*.

† The brachia are not directly respiratory organs, but indirectly, by causing the flow of currents of water over the mantle.

plications is suggested by the fact that most shells with long hinge-lines and high areas, or any other conformation of the shell indicating a short pedicle, close appression to the surface of support, and consequent interference with the mobility of the valves, are plicate. This is notably true of the *Spiriferacea* and *Terebratulacea.* On the other hand, most shells with prominent ventral beak and apical foramen (many *Athyridæ* and *Terebratulidæ*), a conformation indicating great freedom of movement of the valves, are non-plicate. Among Atremata and Neotremata, where there is often very great mobility of the valves, plications are lacking; and as has been recently pointed out by Morse* the setæ are here well developed and serve the purpose of strainers. In articulate brachiopods the setæ are usually small or aborted. A possibly analogous correlation is seen in the Pelecypoda between the development of plications and siphons. When the siphons are well developed and control the incurrent and excurrent water, the shell is seldom plicate. On the other hand, many of the shells which lack siphons are strongly plicate (*Pectinacea*, *Ostracea*, *Pteriacea*, *Arcacea*, *etc.*).† There is in both brachiopods and pelecypods a tendency to improvise tubes for the passage of incurrent and excurrent water by throwing the margins of the mantle into folds or wrinkles. Morse (*loc.cit.*) has pointed this out in the case of *Lingula lepidula*, and N. Yatsu‡ in that of *L. anatina*. Some fossil shells suggest the same thing (*Pentamerus*, *Leptæna*).§ Prof. R. T. Jackson informs me that the same is true of some asiphonate Pelecypoda. This tendency may have had something to do in both classes with the initiation of plications. There is undoubtedly also a relation between habitat and plication. It is well known that oysters grow smooth or plicate according to the nature of the bottom and purity of the water. Woodward‖ has pointed out an analogous relation between shell ornamentation and habitat among the Brachiopoda. Prof. H. S. Williams¶ believes that plications in the Brachiopoda are due to accelerated peripheral growth of the mantle. This is rather a restatement of fact than an explanation of it. In some brachiopods the plications of the nepionic shell correspond accurately with the setæ.** The prolongations of

* Mem. Bos. Soc. Nat. Hist., v, No. 8, 1902.

† I am aware of the fact that even in asiphonate Pelecypods, water is not necessarily admitted along the whole margin of the mantle but is more or less confined to definite parts of it. See Rémy Perrier, Éléments d'Anatomie Comparée, p. 661.

‡ On the habits of Japanese *Lingula*, Annotationes Zool. Jap. iv, pt. 2, 1902, pp. 63, 64.

§ Davidson, Sil. Brachiopoda, 1869, pl. xxxix, fig. 4.

‖ Quoted by Œhlert in Fischer's Manuel de Conchyliologie, p. 1243.

¶ Geol. Biol., p. 309.

** See Morse, Mem. Bos. Soc. Nat. Hist., ii. pt. i, No. 2, 1871, pl. 1, fig. 26.

these nepionic plications would account for shell plication in some instances; and probably striæ are usually due to the presence of setæ and other organs in the mantle margins.

Progressive and retrogressive evolution.—The greater part of the history of *Platystrophia* is progressive. There may indeed have been retrogression in minor details accompanying general progressive evolution; as in the obsolescence of the secondary plications of the sinus of *P. laticosta* and *P. costata.* There was a return in this particular to a primitive condition. In the later history of the group genuinely retrogressive series are met with, notably *P. acutilirata* (upper Richmond form) and *Bilobites varicus.* *P. lynx* of the upper Lorraine, we have seen, presents markedly gerontic characters but scarcely gives rise to a truly retrogressive series. General retrogression, in the *Platystrophia* group, in every case heralds extinction. Characters added at various times during the history of the genus are lost in the inverse order of their acquisition. For example, in *P. acutilirata* the latest added character is the acuminate cardinal angles. This is the first feature to disappear in retrogression. In extreme retrogression the sinus decreases in depth and angularity, the auriculation of the cardinal extremities disappears, and the shell assumes a markedly *lynx*-like aspect. *Bilobites varicus,* as pointed out by Beecher,* first loses the pronounced bilobation that characterizes *B. verneuilianus.* It never loses the vestigial median plication of the ventral sinus. The older a character, the more persistent it is.

In all these cases of retrogression the process seems to be due to the acceleration of gerontic modifications. This is especially well shown in *P. acutilirata,* where we first meet with an occasional gerontic individual which has lost its acuminate cardinal angles and finally in higher zones find the whole group thus affected, and the gerontic modifications appearing in early ephebic stages. I have noticed a precisely parallel case in *Spirifer mucronatus* of the Devonian. Some of the later forms of this species are so modified by the acceleration of gerontic characters that the cardinal angles approximate 90°, the more acuminate stages being indicated by the growth lines on the posterior portion of the shell. The inverse order of disappearance of characters applies here, also, as it seems to in practically all retrogressive types.†

Yale University Museum, New Haven, Conn., Nov., 1902.

* This Journal, (3), xlii, 1891, p. 56.

† For other examples of retrogression, see the various papers of Beecher and Beecher and Clarke on the development of the Brachiopoda, and Beecher's chapter on the Trilobita in Eastman's translation of Zittel's Grundzüge. See also Hyatt's numerous papers on the Cephalopoda, and Jackson's memoir on the Phylogeny of the Pelecypoda, Mem. Bos. Soc. Nat. Hist., iv, 1890.

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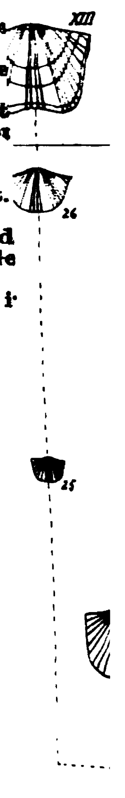

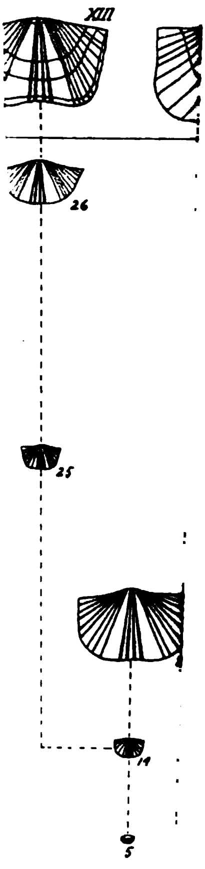

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Art. XI.—*Note of the Condition of Platinum in the Nickel-Copper Ores from Sudbury;* by **Chas. W. Dickson.***

The determination of the new mineral sperrylite ($PtAs_2$) by Professors Penfield and Wells, in 1889,† has led to a great deal of speculation since, as to the condition of platinum in various ores where it is known to occur. This applies especially to the nickel-copper ores of the Sudbury District, Ont., in which a small percentage of the platinum metals seems to be always present.

As originally discovered by Mr. F. L. Sperry, the sperrylite occurred in the loose gossan material, which consisted of gravel containing iron and copper oxides and sulphides, and which was found near a quartz vein at the Vermilion mine in Algoma, Ontario. In 1896, T. L. Walker‡ made some further investigations on this gossan from the Vermilion mine, and decided that the sperrylite occurred in connection with the chalcopyrite, while none could be detected associated with the fragments of pyrrhotite. Summing up, he says: "In this connection it may be mentioned that in all the copper-nickel mines of the Sudbury District traces of the metals of the platinum group are found, and also that the nickel matte from mines low in copper contains very little platinum, while mines richer in copper afford a matte proportionately richer in platinum. In short, the platinum contents of the nickel matte in the Sudbury District is directly proportional to the copper contents; viz., proportional to the amount of copper pyrites in the original ore. This fact, taken in connection with the detection of sperrylite in fragments of chalcopyrite, while a careful search did not reveal it in the pyrrhotite fragments, renders it very probable that the platinum found in the Sudbury District in the copper-nickel mines in general occurs as sperrylite, and that the mineral occurs generally, if not exclusively, in chalcopyrite." Thus, while the opinion has been quite general that the platinum in the unaltered ores of the nickel-copper mines of the Sudbury District was in the form of the arsenide, the matter was not proved directly, and the conviction was inferred only from analogy with the occurrence at the Vermilion mine.

Professor Vogt has recently§ published the results of a number of analyses of various ores from the Norwegian nickeliferous pyrrhotite deposits. He finds that a small but appreciable quantity of the metals of the platinum group is always present. The copper minerals, as in the Canadian occurrences, contain the largest amount. His opinion is that the platinum is present as sperrylite, connected with the chalcopyrite; but this has not as yet been proved, though the results obtained in

* 1851 Exhibition Scholar, from Queen's University, Kingston, Ont.
† This Journal (3) xxxvii, pp. 67, 71, 1889. ‡ This Journal (4), i, p. 110, 1896.
§ "Platingehalt in norwegischen nickelerz.", Ziet. für prak. Geol., Aug. 1902.

the experiments here described give additional weight to his conclusion.

With the object of settling the point, if possible, the present writer began a number of experiments about a year ago, on various samples of ore from the Sudbury District, but without arriving at any conclusive results. Then the discovery of Professors Wells and Penfield,* that the platinum in the copper ores from the Rambler mine, Wyo., was present as sperrylite, led to some further experiments, one of which proved notably successful. As Walker had shown that the platinum was associated with the chalcopyrite, this mineral was selected as the object of special investigation. A number of samples from different localities were freed from pyrrhotite and other foreign minerals as well as possible, and were used for the tests. The only one, however, which gave satisfactory results was some massive and almost pure chalcopyrite from the Victoria mine, about twenty miles west of Sudbury. Seventy-five grams of the coarsely crushed mineral were treated a number of times with hot nitric acid, till all the sulphides were decomposed. The sulphur which separated was removed by means of carbon bisulphide, and the residue treated several times with sulphuric and hydrofluoric acids, to remove the quartz and silicates. The final residue consisted of quite a large number of small and very brilliant tin-white crystals and fragments, resembling sperrylite. On a qualitative examination the mineral proved beyond doubt to be the arsenide of platinum. It yielded a crystalline sublimate of As_2O_3 in the open tube. On long continued treatment with hot concentrated aqua regia some of it was dissolved, and on the addition of ammonium chloride gave the well known yellow crystalline precipitate of ammonium-platinic chloride. The test of dropping some of the fragments on a piece of hot platinum foil was also tried. The mineral melted, sprouted, and gave off white fumes, so there can be no doubt as to its nature, chemically.

Some of the crystals were very well developed, and fifteen or twenty of them ranged between 0·5–1^{mm} in diameter. A number also presented interesting and complicated combinations of forms, and in order to prove the crystallography of the mineral, and to compare it with that from the locality of the original discovery, some of the angles were measured. Nearly all the crystals are more or less distorted; a modified, elongated cube being perhaps the commonest. The largest and most perfect crystal (an elongated cube) had the following faces: cube (001), octahedron (111), pyritohedron (210), and trapezohedron (211), besides some smaller indefinite faces which could not be accurately determined.

The measurements are as follows:—

* This Journal (4), xiii, 95, 1902.

Faces.	Observed Angles.	Calculated Angles.
100 ∧ 100	90° 3′	90°
"	90° 1′	"
100 ∧ 111	54° 41′	54° 44′ 8″
"	54° 46′	"
111 ∧ $\bar{1}$11	70° 28′	70° 31′ 44″
"	70° 29′	"
210 ∧ 100	26° 40′	26° 34′
"	26° 38′	"
211 ∧ 100	35° 14′	35° 15′ 45″
"	35° 11′	"

A somewhat smaller crystal yielded a variety of forms, including two trapezohedrons (211 and 411), with the following measurements:

Faces.	Observed Angles.	Calculated Angles.
211 ∧ 111	19° 28′	19° 28′ 30″
"	19° 24′	"
411 ∧ 111	35° 17′	35° 15′ 45″
"	35° 18′	"

The dodecahedron (110) was also observed on a number of crystals. It was noticed that the octahedral faces gave the best reflections, while those from the trapezohedrons were fainter, and those from the cube were often multiple.

Of the faces found, the trapezohedrons (211 and 411) had not been recognized till the work of Professors Nicol (School of Mining, Kingston, Ont.) and Goldschmidt, during the past summer.* In addition to the forms already described (111, 100,* 102 and 110), these workers discovered a large number of new and interesting faces, including the two found on this material. It is thus evident that the sperrylite from the new source and locality (Victoria mine) is identical, chemically and mineralogically, with that as originally described by Professors Penfield and Wells from the Vermilion mine.

While these experiments will not prove that all the platinum is present as sperrylite, they at least remove the doubt as to its condition, in part at least, in the unaltered ore. Even the platinum which has been found in connection with the nickel mineral polydymite will no doubt prove to be present as the arsenide, if enough material can be made available for careful work.†

These experiments were carried on, partly in the laboratory of the School of Mining, Kingston, Ont., which was kindly placed at the writer's disposal, and partly in the laboratories of the Geological and Mineralogical Departments, Columbia University, and thanks are due to Dr. W. L. Goodwin, of Kingston, and Professor Kemp, of Columbia, for facilitating the work. The writer is also indebted to Dr. A. F. Rogers, of the Department of Mineralogy, Columbia, for his kindness in assisting with the goniometrical determinations.

Columbia University, New York, Dec. 12, 1902.

* This Journal (4) xv. † This Journal (3), xxxvii, 67, 1889.

ART. XII. — *Lecture Experiment on Surface Tension and Superficial Viscosity;* by JOHN E. BURBANK.

WHILE carrying on some experimental work in regard to the motion of solids in water, the author made a very interesting observation on the elastic properties of liquid surfaces, and as no mention of this particular form of the experiment is to be found in the text-books or magazines at hand, there is presented here a brief description of the experiment for the benefit of those who might wish to use it as a lecture-room demonstration of the properties of liquid surfaces. No attempt was made to take any quantitative measurements of any kind as the experiment was considered merely qualitative. And no figures are given, since any one can readily understand the conditions without them.

A ball of paraffin wax, 4·3^{cms} diameter, was made as nearly spherical as possible, and a small mass of lead inserted in it so as to keep it in a fixed position and prevent rotation as it moved up or down in a mass of water; by using different amounts of lead it is possible to so adjust the weight of the ball that it will move very slowly. If the ball and counterweight be such that the mean specific gravity of the mass be a very little less than that of water, it will rise with a velocity of from two to ten centimeters per second. If the adjustment be made so that the ball will have an upward velocity of about 4^{cms} per second, and then the ball submerged to a depth of about 40^{cms} in a jar of water and then allowed to rise, on reaching the surface film of the water it raises the latter through a small distance causing it to stretch; the action of the film is to contract and force the ball down into the water to a depth of about 10^{cms}. In many cases the ball would rebound the second, and even the third time, but generally the contamination of the water film by the paraffin caused the surface to break after the second rebound. If the ball be tried repeatedly in the same vessel of water the surface soon becomes so contaminated that only one rebound is observed.

The force of gravity is not the whole cause of this rebound, as we shall see when we consider the rebound of liquid spheres under the same conditions. In order to show that the rebound was chiefly due to the action of the film, the two following tests were made:

1. The height to which the ball rose at the instant of first rebound was carefully noted, then the height to which the ball rose after finally breaking the surface was found to be practi-

cally the same; no allowance could be made, however, for the effect between the film and the paraffin in the last position.

2. After noting the height to which the ball rose at first impact, the ball was removed from the water so as to break the film, then lowered in again to the same height as at impact and allowed to fall. In no case was the distance fallen as great as on rebound from the film. Both of these methods were very rough, and only comparative measurements were taken.

A wooden ball of $3 \cdot 4^{cms}$ diameter, weighted in same way as paraffin, was next tried; the results were of the same nature but not so strong owing to the capillary action of the film on the slightly rough surface of the ball. With this ball it was possible to get velocities sufficient to break the film but no observations were taken in regard to this point.

The paraffin ball was then tried in alcohol and similar results to those in water were obtained. It was next tried in kerosene oil but the clinging of a layer of oil prevented any positive results. It was finally tried in a strong solution of soapy water, which would have a film with great viscosity and small tension; a film of this kind should show a greater rebound than pure water, other conditions being the same, because the actual time interval of contact between the ball and film would be greater than in pure water on account of less tension of film; this greater time interval would allow the eddies in the wake of the ball more time to die out and thus less resistance would be opposed to the rebound. Observation showed that this reasoning was correct, the distance of rebound being decidedly greater than from a surface of pure water.

Liquid spheres rebounding from liquid surfaces.—Kerosene of specific gravity ·78 was run into the bottom of a jar of water about 40^{cms} deep, by means of a long tube ending in a U-shaped capillary small enough so that the drops escaped at the rate of 2 or 3 per second; these drops would rise with considerable velocity and at the very first, while the surface of the water was clean, many of them would rebound, but only through about $1/2^{cm}$; this small rebound is due partly to the difference in density between kerosene and water, but chiefly to the flattening of the drop. After a few drops of kerosene have risen to the surface none of the drops will rebound but the flattening effect is more noticeable; this would also be explained by the longer time interval of contact between drop and film; the shorter the interval of contact the more nearly the drop behaves like a solid sphere, precisely similar to the effect of striking the surface of water with the hand. A jar containing a little water was filled with kerosene, and alcohol of specific gravity about ·81 was run in from a pipette; the rebound of the alcohol from the film between the kerosene and water was very evident;

from the previous reasoning one might expect the viscosity of the film to destroy the rebound, but it is probable that while much of it is destroyed in this way, yet the velocity of the drop and its slight difference in density from the kerosene, make this rebound a maximum. This is an extremely good illustration of the tendency of a liquid to form in drops; if the alcohol be run in in a fine stream it breaks up into numberless drops, and the surfaces of these drops are seen to be in rotational motion; sometimes several of these drops crowd together and fall as a single mass. The next trial was of olive oil in a mixture of alcohol and water having a slightly greater density than that of the oil itself; no rebound was observed, the velocity being very small, and the flattening of the drop at impact very pronounced; this observation bears out the reasoning in regard to the action of the kerosene after the surface of the water has been contaminated by the first few drops.

It should be noted that the velocity of a solid sphere falling in a liquid of uniform density becomes constant after a very short interval of time; this has been proved by Allen * and others, and of course the same would apply to a solid sphere if rising; except for the rotational motion it would doubtless apply with similar accuracy to the motion of liquid drops in a fluid of different density. In case a solid sphere is used of nearly the same density as the liquid, a slight change in temperature will made a great difference in velocity of rise, and also in rebounding effect.

Conclusion.—As has been shown by Stokes, to whom reference is made in Allen's paper cited above, there is a certain critical velocity for a sphere moving in a mass of fluid; for velocities above this value, eddying motion is a disturbing factor in the mathematical calculations, for velocities less than the "critical" the mathematical equations hold. From these considerations we might expect that for each sphere there would be a certain "critical" velocity which would depend on the difference in density between the liquid and the sphere, on the nature of the surface of the sphere, and on the surface tension and superficial viscosity of the liquid film; when this particular velocity is attained we would then have maximum force of rebound.

Physical Laboratory,
Univ. of Maine, Orono, Maine.

* Motion of a Sphere in a Viscous Fluid, H. S. Allen, Phil. Mag., l, 1900.

Art. XIII.—*Mylagaulodon, a New Rodent from the Upper John Day of Oregon;* by W. J. Sinclair.

Dr. W. D. Matthew, in his revision of the Mylagauli, enumerates* five species referable to two genera, all of which are either from the Loup Fork or the Deep River beds. No representative of this family has so far been described from the John Day. Two years ago, the members of the University of California party discovered the skull of a small rodent in the uppermost beds of the Upper John Day on Johnson Creek, Wheeler Co., Oregon. The specimen is unique, differing from anything known. It is believed to represent a transitional stage between *Allomys hippodus* of the Middle John Day and the Loup Fork *Mylagaulus*. The type specimen (see fig.) is a poorly preserved cranium (Pal. Museum, No. 1652).

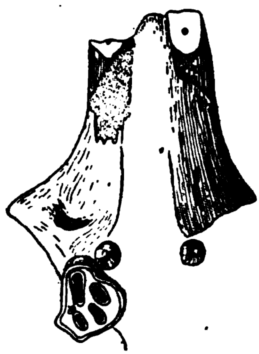

Fig. 1. ***Mylagaulodon angulatus*, gen. et sp. nov., Upper John Day, $\times \frac{2}{1}$.**

The dentition is imperfectly preserved, but the dental formula was probably reduced below that of *Allomys*. The third superior premolar is a simple cylindrical tooth, as in that genus. The fourth premolar is hypsodont. On the triturating surface of this tooth there are four antero-posteriorly elongated lakes, with a fifth small circular lake situated between and external to the two large outer lakes. On the outer side of the antero-external lake there is a straight enamel ridge narrower than the circular bands inclosing the lakes. This ridge and the small circular lake would probably disappear in the worn tooth. The external side of the crown is flat with a prominent postero-external angulation, which suggested the specific name *angulatus*. The antero-external angle of the crown is rounded.

* Bulletin Am. Mus. Nat. Hist., vol. xvi, pp. 291–310.

There is no trace of cement externally on the crown of either premolar. Molars are not preserved. The poor state of preservation of the cranium prevents a detailed discussion. The infra-orbital foramen is larger than in *Allomys hippodus*, and is situated close to the zygoma.

Measurements.

Approximate length of the skull	46	mm.
Length of diastema anterior to pm. 3	11	"
Antero-posterior diameter of enlarged premolar crown	5·5	"
Transverse diameter of enlarged premolar crown	5	"
Antero-posterior diameter of pm. 3	1·5	"
Transverse diameter of pm. 3	1·5	"
Greatest width of incisor	2·5	"

The species is referred to a new genus, *Mylagaulodon*, so named from the resemblance of the enlarged premolar to the teeth of the Mylagauli. In the retention of the conical premolar, the genus resembles *Allomys*, from which it differs in the loss of the antero-external buttress between the outer crescents in the fourth premolar, the rounding of the antero-external angulation, and the hypsodont character of the tooth. A somewhat similar arrangement of the enamel lakes might be attained in worn teeth of *Allomys hippodus*. *Mylagaulodon* is sufficiently contrasted with the beavers in the antero-posterior elongation of the enamel lakes, in which it agrees with *Mylagaulus*, differing from that genus, however, not only in the shape of the fourth premolar, but in the retention of the cylindrical third premolar as in most of the Sciuridæ. It is believed that reduction either in size or number of the molars must have taken place in *Mylagaulodon*, owing to the lack of space on the maxillary to accommodate three more teeth of the same size as the last premolar.

The presence of this transitional form in the uppermost John Day is important in the light of the known occurrence of *Mylagaulus* in the Mascall beds at Cottonwood, Oregon. It is in the Upper John Day that the ancestors of the oldest Loup Fork fauna should be sought with the most confidence. It is possible that the evolution of the Mylagauli took place in the Oregon.

Paleontological Laboratory,
University of California, Berkeley, Cal.

Art. XIV.—*Studies in the Cyperaceæ;* by Theo. Holm. XVIII. On *Carex fusca* and *Carex bipartita* All.

The futile endeavor on the part of certain modern systematists to verify plant-species, established by the earlier authors, by means of their herbarium-specimens but regardless of the diagnoses, has resulted in some very strange discoveries, so strange indeed that they are hardly to be believed. And the excuse for not considering the diagnoses is simply the belief that the herbarium-specimens are to be looked upon as "types" of the respective species. Thus one author states that he "has seen the very oldest types, so far as they are known to exist," of the North American *Carices;* if he had said "supposed to be types" he might have come nearer the truth.

That this kind of work does not fall within the scope of scientific research is certain, and one might think that it should be ignored altogether. But experience has taught us that some of these results have, nevertheless, been accepted by several writers abroad and in this country, and we have thought, therefore, to present some samples of what may be called "type-species botany," for which we have selected Allioni's *C. fusca* and *C. bipartita*, of which the former name has been accepted in the place of the younger *C. Buxbaumii* Wahlbg., while the latter has been applied as the earliest appellation for Willdenow's *Kobresia caricina.*

It would appear at once that the verification of such old species means a good deal more than a hasty examination of the specimens, that no small amount of literary research is involved, a study of the author's method of describing, of citing, the history of the herbarium as it has been left at his death, etc.; the last question is of no small importance, as we shall demonstrate in the following pages. And if these points were duly considered so much stress would not be laid upon "names" alone, as is the case at present and has been, we regret to say, during the last decennium. "Tum primum homines ipsas res neglexerunt, quum nimio studio nomina quærere cœperunt," said Galenus.

Literary research, however, even if it does not reach beyond the history of a plant-name, is of some importance, if properly conducted, but is seldom productive of results commensurate to the time expended. There is another phase of this so called type-species botany which is especially objectionable; this is the confusing results which ultimately arise as a consequence of taking certain specimens to be types whether they agree with the diagnosis or not. In the latter instance a diagnosis

may look as if it were entirely wrong; thus we might infer that the author—he be an Allioni, Linnæus, Willdenow, Robert Brown or anyone whose specimens have fallen into the hands of "type-species botanists"—did not know how to describe a common plant. Thus is the "type" of Robert Brown's *Carex affinis* said to be *Kobresia scirpina* L.,* although Robert Brown's diagnosis calls for a *Carex*, and although he enumerates the Kobresia in the same list identified as a Kobresia. It would hardly be probable to suppose that Robert Brown should have made a *Carex* out of this genus after he had examined and identified other specimens as a *Kobresia;* it seems much more reasonable to believe that the plant Professor Bailey saw was either not a *Kobresia*, or that the specimens were not Robert Brown's type; the latter conclusion is more natural inasmuch as Robert Brown did not work with types. Another example may be mentioned in regard to suppressing Dewey's *Carex petasata:* "The original sheet is in Herb. Torrey. It contains 3 plants, *C. lagopina*, *C. festiva* and *C. Liddoni*, to all of which Dewey's description will equally apply." And, therefore, *C. petasata* "cannot be pressed into service"! This is evidently one of the farthest points to which "type-species botany" has reached, when we consider the fact that the name *C. Preslii* is preferred for this species, although with the admission that it is a "guess name," and that Dewey sent good examples of his *C. petasata* authenticated by his hand to Boott, who had them figured, and our friend Mr. C. B. Clarke of Kew has informed us that these specimens were "not mixed." Drejer's *Carex hyperborea* is, regardless of the diagnosis and opinions expressed by Blytt, Elias Fries and other critical students of the genus, simply referred to *Carex vulgaris* on the grounds that some few mounted specimens were taken to be "the type." These are only a few out of many cases where specimens have been given preference to the diagnosis and the result is, of course, not unexpected. And the difficulty which confronts us when studying certain plants in the earlier herbaria lies in the fact that, as a rule, we know so very little about the real history of these herbaria. One thing, however, should be readily emphasized from the study of the old literature, that the botanists did not work with types, and it requires, indeed, but very little research to make us feel convinced of that. Moreover, there is no indication whatever to prove that the specimens preserved in these old herbaria are those that served as base for the diagnosis.

It might be of some interest to the reader when we present

*For references consult the Bibliography appended to this paper.

a brief sketch of certain points relating to the herbaria of Linnæus and Willdenow so as to demonstrate the fact that it is pure imagination to believe that the specimens preserved are "the types of the species." The Linnæan herbarium has been thoroughly studied and its actual importance been explained by various authors, for instance by Elias Fries and Hartman. We owe to the former an excellent account of the condition of the herbarium, about Linnæus' method of collecting, citing, etc., and Hartman has given a report in full about the Scandinavian plants that are represented in the herbarium. It is a well known fact that a large number of the specimens collected by Linnæus do not correspond with the diagnosis, written by himself, and the reason for this is, thus, explained: Linnæus did not preserve such material as he had already described, and which he described in the field, but he preserved such specimens which were either very rare and not readily accessible or such as he thought differed somewhat from those already described. These he laid into the herbarium with the intention of comparing and studying them later. It is, thus, the fact that almost none of the plants which Linnæus mentions in his narratives of his journeys are preserved from these stations, but that they are represented by specimens from entirely different places or countries, which seems to prove that Linnæus' writings were not based upon "herbarium-specimens," but upon studies in the field. Linnæus' quotations are mostly misunderstood. He explains himself, however, that these do not necessarily need to indicate that the plants are identical, but that the figure—and he refers mostly to figures—does give some idea of the habit and to some extent expressing the general aspect of the plant. It is, thus, evident that Linnæus' species must be studied by means of his diagnosis and not from the specimens or quotations, and this is, of course, in many instances quite a difficult task.

However some, and indeed no small, assistance is rendered by the fact that Linnæus did not enumerate and describe his species "haphazard," but that he followed certain rules in the disposition of these. One of these principles adopted by Linnæus is for instance noticeable in the description of the species of *Stellaria*, where he commences with the one that possesses the broadest leaf and ends with those of which the leaves are the smallest and narrowest: 1. *Stellaria nemorum* "foliis cordatis," 2. *S. dichotoma* "f. ovatis," 3. *S. radians*, "f. lanceolatis," 4. *S. graminea* "f. linearibus" and 5. *S. biflora* "f. subulatis." His arrangement of the *Carices* follows a similar principle, though especially applied to the composition of the inflorescence: *Carex dioica* "spica simplici, dioica," *C. capitata* "spica simpl. androgyna," *C. baldensis* "spicis

androgynis," *C. flava* "spicis sexu distinctis," etc. By studying these various rules followed by Linnæus in disposing of the species, we have often succeeded in identifying several of his critical species.

But the assumption that Linnæus should have intended the first species in each genus as being the generic type, has no foundation; his classification of species seems to us too artificial, as stated above, but has the advantage, on the other hand, of being an excellent guide for determining his species. There are so many variations in his rules for arranging the species, that no critical reader should ever get the impression that the first species was intended to be the type of the genus; sometimes the largest and highest developed species, for instance in *Stellaria*, is the first enumerated, or the lowest one as in *Carex;* a most complicated classification is exemplified in his *Amaryllis* and many others, where no attempt has been made to classify the species in anything like a phyletic order, but only in such a way that the determination may be rendered as easy as possible. The principles of Linnæus for the establishment of the genera and species must be studied in his Philosophia botanica, where he gives a complete account of the various characters, their meaning and respective importance.

We will now proceed to give a few remarks upon the very comprehensive herbarium of Willdenow in accordance with the criticism offered by Schlechtendahl. We need simply to repeat that most important information that Willdenow's herbarium does not contain specimens of all the species which are enumerated in his Species plantarum. This is readily to be seen from the fact that Willdenow, who made very extensive exchanges with other botanists, very often removed the original specimens when he received better, more completely preserved ones of what "he took to be" the same species. In a number of cases they were not the same, and the original ones were sent out in exchange for others. Furthermore that Willdenow, like Linnæus, put many plants in his herbarium "ad interim" under certain species, which he desired to keep for future studies, but many of these were never studied or more carefully compared. Last, not least, when Willdenow died a number of specimens and labels were mixed in such cases, where more than one had been laid on the same sheet. Willdenow's herbarium must, therefore, always be treated with the greatest precaution when the intention is to match his species in the herbarium with the diagnoses of the respective species in his Species plantarum, with the only exception of the Ferns, which are said to have been left in good order and so far undisturbed. So much concerning Willdenow's herbarium, which

certain authors generally agree to consider as being a collection of real "types." It is more than probable that several of the other old herbaria were founded and kept in the same way, but we know so very little about them, and we suggest that the specimens therein preserved should not be given preference for the diagnosis; we might cite here the words of the German botanist Koch, that he desired his species identified not by his herbarium, but by his diagnoses. Nevertheless several modern writers believe in "old types" and that "type-species botany sometimes is our surest way of settling a hard point."

We have, as indicated in the title of this paper, the intention to present some views regarding two *Carices* of Allioni, which seem, in later years, to have been entirely misunderstood, and which have now been restored in such a way that their names have been applied to two plants, regardless of the fact that the restoration is inconsistent with the diagnosis and the geographical distribution. Let us begin with *Carex fusca* All., which is now recognized as identical with *C. Buxbaumii* of Wahlenberg. As security for the correctness of this identification the following statement is offered: "Although Allioni places this species in the section characterized by spicis pluribus sexu distinctis mare unica, it has an androgynous terminal spike. It is represented by a good specimen." And on the strength of this, we might say very unimportant fact, *C. Buxbaumii* is nowadays called *C. fusca* All. by a number of writers in this country and abroad. Any botanist who is familiar with the work of Allioni, with geographical distribution of plants, and with the literature bearing upon the genus *Carex*, will realize at once the ambiguity of the above statement.

Allioni followed the same principle as Linnæus in describing the species of *Carex;* he commenced with those species in which the inflorescence is "spica unica," after which follow those in which there are several androgynous spikes (*C. tripartita, arenaria,* etc.), thereafter those with "spicis pluribus sexu distinctis, mare unica," among which we find *C. fusca.* If the plant which Allioni had in mind had been the real *C. Buxbaumii* he surely would have placed it among those with one terminal, gynæcandrous spike and several lateral, pistillate ones, but he has no member of this group. His diagnosis calls for a plant with one single staminate and three pistillate spikes, while the specimen preserved is said to have a gynæcandrous (androgynous) spike. The question is now to decide whether Allioni made a mistake in his diagnosis, that he overlooked the pistillate flowers in the terminal spike, or whether the specimen in his herbarium was not considered in his

description of the species. We know nothing certain about the matter, but it would be illogical to suppose that Allioni could make such a mistake, when we remember that he is the very author himself of several critical species of *Carex* that are much more difficult to describe than *Carex Buxbaumii.* There is, so far, absolutely nothing to justify us in assuming that the specimen of *C. Buxbaumii* was preserved as the type of *C. fusca.* If it really were the case, we should expect to find citations in the works of other authors who were familiar with Allioni's work and his herbarium; but there are no such citations of *C. fusca* as being identical with Wahlenberg's *C. Buxbaumii*, since the latter has never been known to be common on the Alps of Piemont; as a matter of fact it has never been found there.

It is, for instance, very strange that Schkuhr does not refer to Allioni's plant, but that he established a *C. fusca* of his own; he does not appear to have known *C. Buxbaumii* either, since he describes this as his *C. polygama*, making no allusion whatever to Allioni's plant. The same with Willdenow, who describes *C. Buxbaumii* but without any reference to *C. fusca* of Allioni. First, Gaudin does enumerate Allioni's species, quoting Haller's diagnosis, to which Allioni refers, and Gaudin considered *C. fusca* to be either *C. rigida* Good. or a variety *nigrior* of *C. cæspitosa* L.; the latter plant is among those which Haller's pupils collected, and this is, perhaps, the plant Allioni had in view. Bertoloni in his work upon the Flora of Italy makes no mention neither of *C. fusca* All. or of *C. Buxbaumii* Wahlbg. But finally in Parlatore's Flora Italiana do we learn that *C. Buxbaumii* is a welcome acquisition to the Flora of Italy, having been discovered near Bolzano, but with no reference to its supposed earlier stations in Piemont. If Parlatore had recognized Allioni's *C. fusca* as identical with *C. Buxbaumii*, he would surely have referred to Allioni's species and stated its occurrence "frequens in alpibus, quæ monte Vesulo et Cenisio intercipiuntur." But Parlatore does not give us any information about *C. fusca;* would it not be more correct to surmise that the identity of this species is obscure? Neither Schkuhr, Bertoloni, Parlatore or Willdenow seem to have been able to determine this plant with certainty, and these authors were very familiar with the work of Allioni. It is true that *C. Buxbaumii* does sometimes occur with the terminal spike purely staminate instead of gynæcandrous, yet the plant described by Parlatore (l. c.) is the typical form; the latter, and the specimen, if correctly identified, in Allioni's herbarium has, also, a gynæcandrous spike. Let us presume that even if the specimen in the herbarium be the true *C. Buxbaumii*, that the specimen was not the plant

which Allioni described inasmuch as he immediately after *C. fusca* describes his *C. trigona*, which has been identified as the well-known *C. fulva* Good.

The second example is *Carex bipartita* All., which is now by the same writer explained as *Kobresia caricina* Willd. with the interesting statement that the same species is labeled *C. bipartita* in the herbarium of Balbis, and that its history is clear !—

We regret to say that we have not succeeded in determining the identity of this second species of Allioni with absolute certainty, but the result of our study of the literature seems to be more in favor of it being a true *Carex* than a *Kobresia*, judging from earlier authors who were familiar with Allioni's herbarium. Let us read these authors and let us never forget that we at present have no knowledge whatever of the real conditions of Allioni's herbarium. Allioni described his plant as a species between *Carex arenaria* and *C. paniculata*, where he would hardly have placed his *C. bipartita* if it had been a *Kobresia;* his illustration is not good as a figure of "*Carex lagopina*," but it would be worse, if it were a *Kobresia.* It was Willdenow, who established the genus *Kobresia* and in enumerating the species, among which *K. caricina*, he makes no allusion to *C. bipartita* All. He cites, however, *C. lacustris* Balbis in litt., and as we are told by Professor Bailey, Balbis' specimens are *Kobresia caricina.* It is now interesting to read Gay's account of *Carex lagopina* Wahlbg., since Gay refers as a synonym Allioni's *C. bipartita*, his determination being based upon Allioni's diagnosis, while he states at the same time that Balbis' specimens in the herbarium of Desfontaines contain both this and the *Kobresia.* But Allioni's species was founded upon Bellardi's plants, and these have been verified as *C. lagopina* Wahlbg. by Parlatore (l. c.) This author, who describes both *Kobresia caricina* and *Carex lagopina*, prefers to consider Allioni's plant identical with the latter, on account of the specimens collected by Bellardi.

That Bertoloni (l. c.) enumerated Balbis' specimens as *Kobresia* was evidently due to the fact that the specimens were mixed, as stated above, and he evidently received some specimens of *Kobresia* only. If we now consider these various phases of the question, it seems as if the identification of Bellardi's specimens as *Carex lagopina* is of greater importance than the fact that Balbis collected the same plant, but mixed with *Kobresia.* The specimens collected by Bellardi, not by Balbis, were those upon which Allioni founded his *C. bipartita,* now known as *Carex lagopina* Wahlbg., and this together with the statements from the literature is a point

which heretofore has been overlooked or, perhaps better, been entirely ignored.

The study of the old authors requires much more than a superficial determination of their herbarium-specimens, and no such research should ever have any bearing upon our knowledge of the old masters, their methods of describing, of preserving their plants, etc. We hope that the few points we have discussed in the present paper will be instrumental in suggesting to the systematists the exercise of greater care in accepting new names or combinations as are offered by writers, who have demonstrated their incompetency in studying the old herbaria and interpreting the literature. There seems, so far, no reason to reject *C. Buxbaumii* Wahlbg. and *Kobresia caricina* Willd., and the same result would, no doubt, be reached if we submitted most of the other new combinations to a similar treatment.

Brookland, D. C., October, 1902.

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SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Artificial Diamonds from Fused Silicates.*—Since it seemed probable that natural diamonds have been formed by crystallization from silicate magmas, it occurred to R. v. HASSLINGER, that they might be prepared artificially in this way. A mixture corresponding to the analysis of a diamond-bearing breccia (SiO_2, 40·30; Al_2O_3, 9·45; K_2O, ·90; Na_2O, 4·93; Fe_2O_3, 7·30; MgO, 21·10; CaO, 3·48; loss by ignition, 13·00) was found to be too infusible when the usual methods of heating were used, hence the method of Goldschmidt, the so-called "thermite" process, was employed. Instead of magnesium and aluminum oxides in the mixture which has been given the corresponding amounts of the metals were used, and an amount of ferric oxide sufficient to oxidize them was added. To this mixture carbon was added at the rate of one or two per cent, best in the form of very fine graphite. Portions amounting to about 300^g of this mixture were placed in Hessian crucibles, surrounded by ashes and sand, and ignited, with the result that satisfactory fusions were produced by the reaction and diamonds were formed in the fused mass. It was found impossible to detect the diamonds in thin sections of the slag, because, on account of their hardness, they were broken out in grinding. The mass was accordingly dissolved in a mixture of ammonium fluoride and sulphuric acid, and the insoluble residue was examined. Absolutely colorless and transparent octahedrons were found, having an average diameter of $·05^{mm}$. They scratched ruby and were combustible when heated with oxygen. The results appear to strengthen the theory that natural diamonds have been formed by crystallization from silicates. It should be stated that the metallic iron produced in the experiments was found to contain carbon only in the graphitic and amorphous forms.—*Monatshefte*, xxiii, 817.

H. L. W.

2. *Fluorescence and Phosphorescence of Diamonds.*—Marckwald has observed that the rays emitted by polonium (now called radio-active tellurium; see the following notice) induce fluorescence in diamonds. ROSENHEIM has examined this behavior with diamonds from various localities, and finds that all of them show this property. In this way diamonds could be distinguished from other precious stones, such as ruby, emerald, zircon, topaz, opal, etc. For these experiments the bismuth rod coated with a radioactive substance, recently described by Marckwald, was placed close to the objects, and observation was made in total darkness. The rays emitted by diamonds, under the influence of the rod, act upon the photographic plate, even after an exposure of only two minutes. The rays from the rod also act upon the plate, but these are readily cut off by the interposition of substances such

as tissue paper, celluloid, gutta-percha, and glass, while the rays induced in the diamond show much greater penetration and pass through substances a few millimeters thick. It was found that certain diamonds which phosphoresce after exposure to sunlight or magnesium light, produce no action upon the photographic plate when thus phosphorescing, although the light thus produced, as far as could be judged by the eye, was as great as that induced by the radio-active substance.—*Chem. News*, lxxxvi, 247. H.L.W.

3. *Radio-active Tellurium.*—A short time ago, as noticed in the preceding volume of this Journal (p. 303), MARCKWALD announced that he had separated the radio-active element (polonium) associated with the bismuth derived from the pitchblende of Joachimsthal. This was accomplished by the electrolysis of the bismuth chloride solutions, or more satisfactorily by placing rods of pure bismuth in such solutions. Marckwald has now found that the element thus precipitated corresponds to tellurium as far as its chemical properties have been investigated. To precipitate the tellurium he now adds to the hydrochloric acid solution of bismuth a few drops of stannous chloride solution, and, after warming for a few hours, filters off the resulting black precipitate. This has been found to be more active than the product obtained by the other method, while the residual bismuth salt is almost inactive. The amount of tellurium found was very small, scarcely amounting to one ten-thousandth of the bismuth salt used.—*Berichte*, xxxv, 4239. H. L. W.

4. *Action of Hydrochloric Acid upon Aluminum, Chromium, and Ferric Sulphates.*—By dissolving the sulphates under consideration in strong hydrochloric acid, RECOURA has obtained, upon cooling the solutions, the compounds $AlSO_4Cl \cdot 6H_2O$, $CrSO_4Cl \cdot 6H_2O$, and $Fe_2(SO_4)_3 \cdot H_2SO_4 \cdot 8H_2O$. The results show a marked difference in behavior between the ferric salt and the other sulphates. The chromium compound is interesting from the fact that when dissolved in cold water it gives no immediate precipitate with silver nitrate, although the sulphate radical is entirely precipitated at once by means of barium chloride. When the chromium compound is heated for some time at 85° it loses a molecule of water and changes to $CrSO_4Cl \cdot 5H_2O$. This compound also gives no immediate precipitate with silver nitrate, and, moreover, in very dilute solution it gives no precipitate with barium chloride. The results indicate that the chromium salt with six molecules of water holds the chlorine atom in a complex radical, while the sulphate group ionizes, and that the loss of a molecule of water puts the sulphate group also into the complex radical. The aluminum compound is considered by the author as analogous to the first chromium salt, although it shows no evidence of the existence of a complex radical upon solution in water. —*Bulletin*, xxvii, 1155. H. L. W.

5. *Alkali-metal Hydrides.*—The fact that MOISSAN had prepared a potassium hydride with the formula KH was mentioned in this Journal last year (vol. xiii, p. 240). This author has re-

cently given fuller details in regard to the substance, and has described also the corresponding sodium compound NaH. These hydrides are colorless, transparent and crystalline, and are formed by the action of hydrogen upon the metals at about 360°. At higher temperatures they are decomposed into their elements. They are exceedingly sensitive towards moisture, and are very active chemically. Potassium hydride takes fire when exposed to oxygen at ordinary temperature, while both hydrides ignite spontaneously in chlorine gas. When this combination with chlorine takes place the sodium compound gives a blinding light, and the temperature produced is sufficient to volatilize the sodium chloride which is formed.—*Bulletin*, iii, xxviii, 1140.

H. L. W.

6. *Combustion of the Three Varieties of Carbon.* — MOISSAN has found that diamonds become incandescent in oxygen from 800° to 875°, samples of graphite at about 650° to 700°, and amorphous carbon, according to its character, from 300° to 500°. In each case, however, slow combustion began at a temperature far below that of vivid incandescence ; slow formation of carbon dioxide was observed with diamond at 720°, with graphite at 510°, and with a certain soft variety of charcoal at a temperature as low as 100°. Experiments made with this charcoal in contact with oxygen in sealed tubes, in one case for the space of a year in the dark and in another case in sunlight during the month of September, gave no evidence of slow combustion at ordinary temperatures, for no carbon dioxide was detected.—*Comptes Rendus*, cxxxv, 921. H. L. W.

7. *Ammoniacal Cupric Chlorides.* — By the action of liquid ammonia upon anhydrous cupric chloride, BOUZAT has prepared a blue compound, $CuCl_2 \cdot 6NH_3$. This has a dissociation tension of 760^{mm} at 90°. From this substance, by loss of ammonia, a blue compound, $CuCl_2 \cdot 4NH_3$, and a green one, $CuCl_2 \cdot 2NH_3$, are produced. The first of these gives a tension of 760^{mm} at 140°.—*Comptes Rendus*, cxxxv, 292. H. L. W.

8. *Peculiar Radiation Phenomenon.* — Many observers have noticed a blackening of photographic plates in the dark, under the influence of certain metals and organic bodies. J. W. Russel attributes the action to superoxide of hydrogen. L. GRAETZ has confirmed, in general, the observations of Russel. The latter maintains that the action, although it penetrates various solid organic substances and certain fluids, is not of the nature of a radiation. Graetz does not agree with this conclusion, since the action appears to penetrate thin metallic layers. Aluminum foil, of the thickness employed by Lenard in his research on the cathode rays, is transparent to the action. One also obtains the peculiar radiation if one blows away the vapor of the superoxide of hydrogen from the photographic plate. Experiments of this nature show that it is not the vapor merely which produces the blackening. The radiation is either a direct ether radiation or due to radio-active particles. One can therefore speak of H_2O_2

rays. The author describes certain experiments which support this view, and maintains that one thus obtains a photographic image of chemical processes and has, to a certain measure, a distance working of chemical processes. The author suspects that an active material is present in the H_2O_2 to which the radiation is due.—*Ann. der Physik*, No. 13, 1902, pp. 1100–1110. J. T.

9. *Photography of the Ultra-Red Iron Spectrum.*—The photography of the ultra-violet spectra of alkali and alkali earths demands a standard of iron lines. HANS LEHMANN seeks to supply this need, and gives a table of wave-lengths extending from λ=6811·34 to λ=8690·98. The author refers to the remark of Abney that no lines of certain metals were found in the region of the extreme ultra-red which he photographed with his sensitive plates, and to his conclusion that there is an upper limit to their spectra. Lehmann believes that this supposition is more or less confirmed by his observations.—*Ann. der Physik*, No. 13, 1902, pp. 1330–1333. J. T.

10. *Excited Radio-activity and its Transmission.*—Professor E. RUTHERFORD has made an exhaustive study of this subject, and the conclusions from his prolonged investigations are as follows:

(1) Excited radio-activity produced by thorium and radium compounds is due to the deposits of radio-active matter, which is derived from the emanation given out by these bodies.

(2) Excited radio-activity is transmitted by positively charged carriers, produced from the emanation, which travel in an electric field with about the same velocity as the positive ions produced in air by the Röntgen rays. This velocity (about $1{\cdot}3^{cm}$ per sec. for 1 volt per cm.) is about the same for the carriers of thorium and radium excited activity.

(3) These positively charged carriers are due to the expulsion of a negatively charged body from the molecule of the emanation.

(4) Evidence is adduced for the view that the easily absorbed and apparently non-deviable rays of radio-active substances are due to the expulsion of charged bodies at a high velocity. The rays are thus analogous to the Canal Strahlen of Goldstein, which Wien has shown to be positively charged bodies projected at a great speed. In the case of the emanations the expelled particles are for the most part negative in sign.

(5) In the case of radium about 5 per cent. of the carriers of excited activity are distributed on the anode in a strong electric field.

(6) The excited radiations from thorium due to a short exposure in the presence of the emanations increase, in the course of several hours after removal, to three or four times their initial value.

(7) The emanations and the matter which gives rise to excited activity are the result of a succession of chemical changes occurring in radio-active matter. In thorium there is evidence of at least four distinct chemical changes.—*Phil. Mag.*, Jan. 1903, pp. 95–117. J. T.

11. *Magnetic Declination Tables and Isogonic Charts for 1902;* by L. A. Bauer. 405 pp., 2 pls. Washington: United States Coast Survey.—The increased demand for magnetic data has led the Coast Survey to issue a book bringing down to date the principal facts relating to the earth's magnetism and to construct new magnetic charts.

12. *Manual of Advanced Optics;* by C. R. Mann. 193 pp., 39 figs. Chicago, Scott, Foresman & Co.—The greater practical value of other branches of physics—electricity and magnetism for example, has resulted in the development of these subjects far beyond that of optics in the average physical laboratory. It is, nevertheless, a fact that whether we consider the beauty of the mathematical demonstrations or the accuracy of the measurements, no subject can surpass optics for quantitative physical work. To one who is interested in pure physics the little book just issued by Prof. Mann will prove most welcome. It attempts to do for optics what Carhart and Patterson's *Electrical Measurements* has done for electricity. There are certain features which deserve special mention. First of all, the logical arrangement of the experiments is evident; they grow one out of another as the student is ready for them. The meaning of "resolving power"—a somewhat mysterious term in the mind of most students—is made perfectly clear when illustrated by the simple experiments outlined in connection with it. Measurements in connection with the phenomena of polarized light are clearly outlined and are accompanied by helpful suggestions. The diffraction grating is developed from the conditions of maximum and minimum illumination from light which has passed through two parallel rectangular slits, and two distinct methods of obtaining its resolving power are described. But perhaps the best feature of the work is its description of the Michelson interferometer. When we consider that over sixty papers have been published, embodying investigations with this apparatus, and about as many more discussing these results, it is obvious that physicists have here a most powerful instrument of research. Heretofore the theory and use of this form of the interferometer was to be found only in magazine articles and in foreign works—sources likely to be unavailable for students' use. The book contains a few errors, which a later edition can easily rectify.—J. S. S., Orono, Maine.

II. Geology.

1. *United States Geological Survey.*—The following publications have recently been issued:

Twenty-second Annual Report, 1900–01, Pt. I. 452 pp., 58 pls., 52 figs. The Director's Report (pp. 1–207) shows increased coöperation with the several states and with different branches of the government service—insuring better work at less expense. The appropriation for the year was $997,310, and the increase in appropriation is shown in an increase in scope and

amount of work done. G. H. ELDRIDGE contributes a paper (pp. 219–452) on the Asphalt and Bituminous Rock Deposits of the United States, in which is discussed in detail the nature of the materials and their mode of occurrence.

TWENTY-SECOND ANNUAL REPORT, 1900–01, PT. II. Ore Deposits, 865 pp., 82 pls., 130 figs. The old Tungsten Mine at Trumbull, Conn., is described by Prof. Hobbs. (See this Journal, xiv, 72.) A Preliminary Report on the Lead and Zinc Deposits of the Ozark Region is made by H. F. BAIN, with an Introduction by C. R. VAN HISE, and chapters on Physiography and Geology by GEO. I. ADAMS. Mr. Bain summarizes his conclusions as to the genesis of these ore deposits somewhat as follows: The metals were originally precipitated from shallow seas by organic matter at the time of the formation of the dolomitic limestones of the Cambro-Silurian, and were afterwards concentrated and redeposited by the action of underground waters in fractured or brecciated zones in the Carboniferous limestones, being altered later by superficial agencies, with oxidation and frequently notable enrichment. The Ore Deposits of the Rico Mountains, Colorado, are described by F. L. RANSOME. The ore of the Rico district, which is mostly argentiferous galena, occurs in a number of different formations, as in fissure veins, in bedded or blanket veins, in replacements in limestone and in stocks. Of these types the second has been the most productive. The bulk of the ore has been found in Carboniferous sedimentaries which lie in the central portion of the domical uplift of the Rico Mountains. The area has produced about $10,000,000 worth of ore in the twenty-one years of its existence. At present little mining is being done, and the future of the district is somewhat problematical. Geology and Ore Deposits of the Elkhorn Mining District, Montana, is the subject of a paper by WALTER HARVEY WEED and JOSEPH BARRELL. The Elkhorn district lies on the border between a great granite area and an area of folded sedimentaries. The ore bodies are saddle deposits formed in pitching arches beneath a bed of impervious slate and in a dolomite marble. The deposits were mainly due to the gradual replacement of the dolomite by the substances brought up along a zone of crushed rock by uprising siliceous waters. The metallic contents of the deposit are believed to have come from a gabbro intrusion underlying the limestone. The ore was chiefly a silver carrying smaller values in gold, lead and copper, and was free milling and rich near the surface, but became refractory and of poorer grade in depth. Work in the district was discontinued in 1900. The Gold Belt of the Blue Mountains of Oregon is described by WALDEMAR LINDGREN. This district, situated in the northeastern part of Oregon, forms the most important gold field of the state, yielding at least three-fourths of the total output. The Blue Mountains consist of several cores of old sedimentaries, surrounded by late lavas and igneous rocks of varying types. It is in these old cores that the greater part of the gold and silver

veins of the district are found. The primary deposits are usually normal fissure veins carrying gold, or sulphurets containing gold or silver, or both native gold and sulphurets, in a gangue of quartz. In 1899 the production of the district had a value of something over one million dollars, and the total production up to that time is estimated at a little more than eighteen millions. JOSIAH EDWARD SPURR discusses The Ore Deposits of Monte Cristo, Washington. The mining camp of Monte Cristo is situated on the western slope of the Cascade Range. The rocks of this district are of various igneous types, all belonging to the Tertiary age, along the joints and fractures of which the ores have been deposited. The ores are most abundant near the surface, and the ore minerals show a rough succession from the surface downwards of galena, blende, chalcopyrite, pyrite and arsenopyrite. The upper sulphide zone, which contains the most and the richest ore, was deposited, largely at least, by descending waters. W. E. F.

TWENTY-SECOND ANNUAL REPORT, 1900–01, PT. III. Coal, Oil, Cement, 742 pp., 53 pls., 69 figs. The geology, production, history, etc., of the various coal fields of the United States, including Alaska, are described by experts familiar with the local conditions (pp. 1–571); M. L. Fuller describes the Gaines oil field of Pennsylvania (pp. 529–627); the hydraulic cement industry of Michigan is discussed by Prof. Russell (pp. 635–683); and J. A. Taff contributes a paper on the Chalk of southwestern Arkansas (pp. 693–742).

WATER SUPPLY AND IRRIGATION PAPERS. The following numbers in this series have been issued recently:

Nos. 58.—Storage of Water on Kings River, California; by J. B. Lippincott; 99 pp., 32 pls.

59.—Development and application of Water near San Bernardino, Colton and Riverside, California; by J. B. Lippincott. Part I, 95 pp., 11 pls., 14 figs.

60.—Part II of No. 59; 34 pp.

62 and 63.—Hydrography of the Southern Appalachian Mountain Region; by Henry A. Pressey; 181 pp., 44 pls.

64.—Accuracy of Steam Measurements; by Edward C. Murphy; 95 pp., 4 pls., 30 figs.

65.—Operations at River Stations, 1901, East of Mississippi River; by F. H. Newell; 224 pp.

66.—Operations at River Stations, 1901, West of Mississippi River; by F. H. Newell; 178 pp.

67.—The Motions of Underground Water; by Charles S. Slichter; 101 pp., 8 pls., 50 figs.

68.—Water Storage in the Truckee Basin, California–Nevada; by L. H. Taylor; 87 pp., 8 pls., 20 figs.

69.—Water Powers of the State of Maine; by Henry A. Pressey; 117 pp., 14 pls., 12 figs.

70.—Geology and Water Resources of the Patrick and Goshen Hole Quadrangles, Wyoming–Nebraska; by George I. Adams; 47 pp., 11 pls., 4 figs.

71.—Irrigation Systems of Taxes; by Thomas U. Taylor; 127 pp., 9 pls., 27 figs.

72.—Sewage Pollution in the Metropolitan Area near New York City; by Marshall Ora Leighton; 72 pp., 8 pls., 4 figs.

74.—Water Resources of the State of Colorado; by A. L. Fellows; 147 pp., 14 pls., 5 figs.

2. *Glacial Formations and Drainage Features of the Erie and Ohio Basins;* by FRANK LEVERETT. U. S. Geol. Survey Mon. xli, 781 pp., 26 pl., 8 figs.—The work of Leverett on the Pleistocene deposits of the Great Lakes region constitutes one of the chief contributions to the geology of the United States. Monographs xxxviii and xli are supplementary, the latter describing the area between central Indiana and the Genesee valley of New York. Chapters ii and iii contain a description of the physical features of the region and a discussion of the changes which have occurred in the drainage systems—notably those of the Ohio and its northern tributaries.

The southern border of the glacial drift is found to be not a unit but formed by sheets of widely different ages. The oldest deposit—Kansan or pre-Kansan—is restricted mainly to northwestern Pennsylvania. This sheet consists of a stony till whose great age is determined by the advanced stage of weathering of its pebbles, and also by its erosion. The outwash from the Kansan deposits remains as terraces along the upper Ohio and its tributaries. The second drift sheet—the Illinoian—presents a remarkably flat surface, extending as a fringe ten to sixty miles wide in front of the Wisconsin drift. It has not been found farther east than Holmes County, Ohio.

Following the Illinoian glaciation came the Sangamon and the Peorian interval of deglaciation, separated by the Iowan drift sheet and the main loess deposits. (Complete descriptions with analyses, etc., of these deposits are given in Mon. xxxviii.) The principal drift of the Erie and Ohio basins is Wisconsin, and particularly of the late Wisconsin stage. This is marked by strong moraines on lowland and upland alike, and is described in detail as the morainic systems of the Miami, the Scioto, and the Grand River lobes.

Mr. Leverett discusses in detail (pp. 710–775) the glacial lakes Maumee, Whittlesey, and Warren, which formed in front of the retreating ice sheet as it withdrew into the Huron and Erie basins. The ancient shore lines and outlets have been located with great care. It is shown that the beaches in the eastern part of the Erie basin display a marked warping in contrast to the nearly horizontal attitude of those farther west.

3. *Les Variations periodiques des Glaciers;* par FINSTERWALDER et MURET. 7^me Rapport Com. Int. des Glaciers. *Rapport sur Glaciers Français de 1900 a 1901;* par M. W. KILIAN: *Rêvue de Glaciologie;* par CH. RABOT. 92 pp., 3 pls. (Club Alpin Français. Vol. xxviii.)—The glaciers of the Swiss Alps all show a decrease during 1901 except the Boveyre glacier in the Entre-

mont valley. In the eastern Alps, of the fifty-five glaciers studied, the Vernagt of the Oetzthal is the only one of importance which has lengthened. This glacier has grown remarkably during the past fifty years, and in 1901 advanced fifty meters. The retreat of glaciers in the Italian Alps continues, and several small ones have disappeared. The glaciers of the French Alps show an increased rate of retreat in 1901, and those of the Chambeyron massif are destined soon to disappear. The Marinet group, in spite of successive advances and retreats, is shown by Kilian to have suffered gradual shortening since the Pleistocene. The Alps at the present time offer unequalled opportunity for studying recent glacial work. Speaking generally, the glaciers of other parts of the world were likewise decreasing during 1901.

4. *The Cause of the Glacial Period;* by H. L. True. 174 pp., illustrated. Cincinnati: The Robert Clarke Co.—Dr. True has prepared an interesting summary and discussion of the current theories regarding the cause of the ice age and presents one of his own, viz: that there was a sudden toppling of the earth due to overweighting of certain parts.

5. *Tooth Characters and Revision of North American Species of the Genus Equus;* by J. W. Gidley. Bull. American Museum of Nat. Hist., vol. xiv, pp. 91–141, New York.—Among the many examples of evolution based on fossil material, that of the horse is one of the best known and, to most minds, striking and interesting. From the historical point of view it is also of deep interest as having been the first example in which a complete demonstration of an evolutionary process was ever made. Inseparably linked with the working out of this problem are the names of Huxley, Marsh, and Kowalewsky. And the types perhaps historically most important are those of Marsh in the great collections bequeathed by him to the Museum of Yale University. But it is to be noted, however, that these earlier demonstrations were confined to the more salient facts. The methods of more thorough and systematic collection developed within recent years have rendered it possible to work out the finer details of this evolutionary process, and now promise to place us in possession of the actual specific descent of the several lines of horses. In the contribution before us, Mr. Gidley has determined with exactness the various extinct species of the genus Equus, a most difficult and necessary preliminary to the larger problems of descent. He has been able to do this by investigating in a far more thorough manner than has ever hitherto been attempted, the complicated process of individual tooth change. His further investigations of these problems, based on the splendid collections he has made for the American Museum in the past few years, will be awaited with much interest. W.

6. *The Evolution of the Horse;* by W. D. Matthew. Supplement to the American Museum Journal, vol. iii, No. 1, Jan. 1903.—A popular exposition of the evolution of the horse, which is evidently based upon and called forth by these later discoveries and researches of Mr. Gidley, as reviewed above. W.

III. Miscellaneous Scientific Intelligence.

1. *Publications of the West Hendon House Observatory, Sunderland;* by W. T. Backhouse. Vol. ii, 4to, 161 pp., 60 illustrations. (Hills & Co., Sunderland.) — The first part of this volume is a continuation of the publication which appeared in 1891, "On the Structure of the Sidereal Universe." These include both the observations by the author and discussion by him of the work of others on the forms and groupings noted in the Milky Way, with such structural features as can be observed in other parts of the heavens, including lines and parallelisms, radiated systems of stars, and rifts, of which latter, analogous to the "Coal Sacks" of the southern hemisphere, the author finds less conspicuous examples in photographs of many parts of the heavens. The remainder of the volume consists of observations and comments on the Zodiacal Light, the Aurora, and variable stars. W. B.

2. *A Philosophical Essay on Probabilities;* by Pierre Simon, Marquis de LaPlace. Pp. iv, 196. Translated from the sixth French edition by Frederick Wilson Truscott, and Frederick Lincoln Emory, (New York, John Wiley & Sons, and London, Chapman & Hall, Limited.)—The rendering into English of La Place's classic in a form suitable for the class-room is the work of Professors Truscott and Emory. The translation is timely for two reasons. First, until recently, it could be truly said, on account of the excellence of the matter, that "not much has been added to our subject (probability) since the close of LaPlace's career." Secondly, within four or five years more has been added to the subject, both constructive and destructive, than during the interval of a hundred years. The application of the theory of probabilities to problems of evolution has resulted in new advances in the former to meet the demands of the latter. Among these results, especially significant is the monograph of Karl Pearson, "On the Mathematical Theory of Errors of Judgment, with Special References to the Personal Equation" (Phil. Trans., 1901, pp. 237–299), which apparently overturns the larger part of the current theory of errors of observation as expounded by Merriman and Airy. That such a revival of activity in this field is in progress is perhaps in a measure indicated by the reappearances of this earlier work. J. P. N.

Knowledge Diary and Scientific Hand-book for 1903. Pp. 112. London, 1902. Issued in conjunction with "Knowledge" (Knowledge Office, 326 High Holborn). The varied scope of this volume will be seen from the following statement of its contents. It contains original descriptive articles on the observation of comets and meteors; how to use an equatorial telescope; the microscope and its uses; aids to field botany; hints on meteorology; and monthly astronomical ephemeris. Also the paths of the principal planets for the year, illustrated with charts; astronomical notes and tables, with an account of the celestial phenomena of the year; and twelve star maps showing the night sky for every month in the year, with full descriptive account of the visible constellations and principal stars; a calendar of notable scientific events; an obituary for the year.

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THE

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[FOURTH SERIES.]

Art. XV.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. Wortman.

PART II. PRIMATES.

Introduction.

Somewhat contrary to the accepted order of arrangement usually adopted in treating of the Mammalia, I select next for consideration the Primates, a perfectly natural and homogeneous order, including the Lemurs, Monkeys, and Apes, as well as Man himself. This latter fact invests the study with more than ordinary importance, inasmuch as any additional evidence bearing upon the past history of the group to which man belongs cannot fail to prove of the highest interest, even though it throw only a side light upon the development of the human kind. In view of the belief that the general current of opinion seems to be setting strongly in the direction of the conclusion that the ancestry of the human species, with all its endowments, both mental and physical, must be sooner or later traced with certainty to this source of origin, we may be pardoned for a somewhat exhaustive presentation of the facts which our fossils exhibit.

The various groups of Mammalia have been developed and specialized along diverse lines, the primary cause of which we may regard as having been due to adjustment to varying conditions of environment. It thus happens that different sets of organs have been involved in these changes, so that when we attempt the classification and definition of a natural group, we seek to learn what structures have been most profoundly affected. In the case of the Primates, the enlargement and specialization of the cerebral lobes of the brain constitute the

character *par excellence* in which they have made the greatest progress and in which their evolution has been most marked. The very early development of prehensile hands and feet and the better arrangement of the cerebral circulation have been intimately associated with this progress and are therefore factors of prime taxonomic value and importance. In other words, the Primates have adapted themselves more widely to environment than any other mammalian group, in consequence of which they present well-defined skeletal indices or equivalents, so that whenever they are sufficiently preserved, it is possible to recognize them with a degree of certainty not usually found in other groups of the Mammalia.

Characters of the Cerebral Circulation.

As regards the first set of these characters (the enlargement of the brain), like all other specialized features which come to distinguish a group or order in the final or advanced stages of its evolution, they are of necessity less distinctly marked in the earlier representatives than in the later ones; so that, as we approach the point of origin, greater and greater difficulties are experienced in the application of such characters as a real test of affinity. Thus it is that we find in the less specialized members of the Primates, such as the lemurs and the oldest true monkeys, the relative development of the cerebral hemispheres to be little, if any, greater than that of many of the Insectivora; and were we compelled to depend upon this character alone, it would be in many instances practically impossible to determine whether the animal in question were a Primate or an Insectivore.

Fully recognizing the importance of thus clearly distinguishing between these small-brained Primates and other contiguous groups, in the matter of certain cranial characters, I have been led to make a careful and somewhat exhaustive study of the manner in which the blood supply is furnished to the cerebral hemispheres. Especial attention to this subject has been given, on the assumption that it must have been not only intimately associated with the progressive enlargement of the cerebral hemispheres in the Primates, but was in a way not now clearly understood, in some degree at least, responsible for it. If it is true that certain fundamental differences of this character exist between the several orders, the practical advantage to the paleontologist will be great, since it is only on very rare occasions that he has to deal with complete skeletons of the extinct species. In order to bring out these characters more clearly, I shall first consider the Insectivora, and I begin by quoting Huxley's statement of the course of the entocarotid in the hedge-

hog, figure 100. He says:* "The course of the internal carotid artery is remarkable. When it reaches the base of the skull it enters the tympanum and there divides into two branches, of which one traverses the stapes, and, passing forward in a groove of the roof of the tympanum, enters the skull and gives rise to the middle meningeal and ophthalmic

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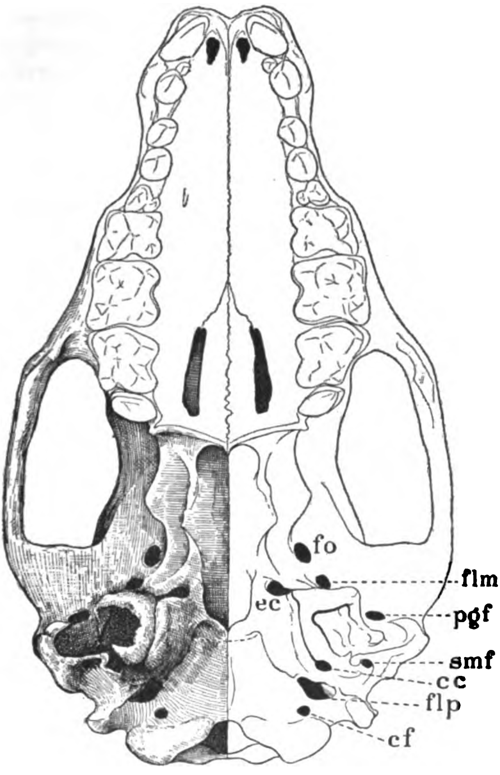

FIGURE 100.—Enlarged view of the base of the skull of *Erinaceus europœus;* showing the foramina.

fo, foramen ovale; *flm*, foramen lacerum medium; *ec*, eustachian canal; *pgf*, postglenoid foramen; *smf*, stylomastoid foramen; *cc*, carotid canal; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

arteries. The other branch passes over the cochlea, enters the skull by a narrow canal near the *sella turcica*, and unites with the circle of Willis."

This course and distribution of the entocarotid is not only characteristic of the hedgehog, but is also found in the follow-

* Anatomy of Vertebrated Animals, 1872, p. 380.

ing additional genera of the Insectivora: viz., *Gymnura*, *Tupaia*, *Talpa*, *Scalops*, *Condylura*, *Sorex*, *Myogale*, *Centetes*, *Hemicentetes*, *Ericulus*, *Solenodon*, *Chrysochloris*, *Leptictis*, and *Ictops*. This list, it will be seen, includes typical representatives of all living families except the Macroscelidæ and Potamogalidæ. I have not been able to examine the skulls of any members of these two families, but I have very little doubt that it is true of them also, and that this course of

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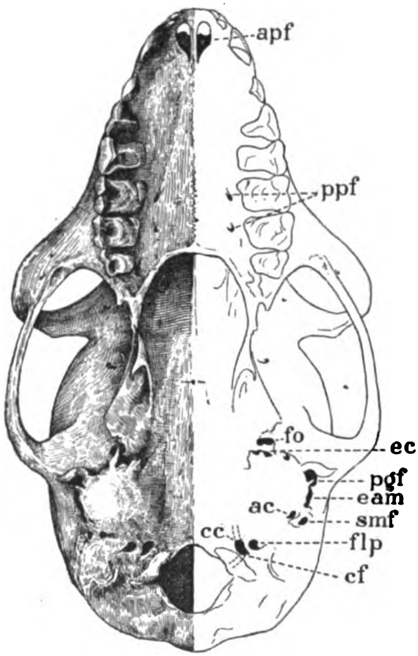

FIGURE 101.—View of the base of the skull of *Lemur catta*.

apf, anterior palatine foramen; *ppf*, posterior palatine foramina; *fo*, foramen ovale; *ec*, eustachian canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *ac*, accessory carotid canal; *smf*, stylomastoid foramen; *flp*, foramen lacerum posticum; *cc*, carotid canal; *cf*, condyloid foramen.

the artery is a constant and important diagnostic feature of the Insectivore skull. It is of interest to note that in *Galeopithecus* the course of the artery is not like that in other Insectivora, but agrees with that of the bats and one important group of the lemurs. It may be also added that this course of the artery, according to Owen,* is true of some, if not all, Rodentia. The practical application of this knowledge of the course of the entocarotid, to the classification of certain fossil

* Anatomy of Vertebrates, 1868, vol. iii, p. 229.

forms of supposed Insectivora, is thus rendered possible by the distinct grooves which both branches make in the under side of the petrosal. In the case of all the recent forms which I have examined, as well as of some of the well-known fossil types, the direction of the two branches can be determined with ease.

Turning next to Primates, we find that in certain of the lemurs, notably the Indrisinæ and Lemurinæ, the main branch of the entocarotid artery enters the cranial cavity through a canal at the postero-internal junction of the tympanic bulla and the basioccipital, near the point of exit of the condyloid foramen, figure 101. The main artery passes forward and into the cranial chamber at the side of the *medulla*, wholly within the posterior or cerebellar fossa. In some species of these two subfamilies, there is a small canal entering the bulla in the position corresponding to the foramen for the entocarotid in the Insectivora; this is undoubtedly the homologue of the entocarotid in that group, but it is small and inconsiderable, and appears to be practically absent in all except *Lemur* and *Propithecus*. In these two genera, especially the latter, the tympanic branch is nearly as large as the main artery.

In the remaining species of the living Lemuroidea, there is no canal for the entocarotid in the position above described for *Lemur* and *Propithecus*, but there is a large and conspicuous *foramen lacerum medium*, which has its usual position at the antero-internal angle of the petro-tympanic, figure 102. Mivart constantly spoke of this foramen as the carotid canal, and from certain distinctive evidences of an arterial vessel entering the cranial cavity in this situation, in many imperfectly prepared skulls of these species which I have examined, there can be apparently no doubt that the office of this foramen is the transmission of the main entocarotid artery. It will be thus seen that there are two distinct types of entocarotid circulation in the Lemuroidea, both of which are sufficiently distinct from the Insectivora to afford reliable diagnostic characters.

In the remaining Primates or Anthropoidea, including *Tarsius*, the entocarotid circulation presents another arrangement. In this group, the course of the artery corresponds more nearly with that of the Insectivora, in that its canal traverses the petro-tympanic chamber. There is an important difference in the two, however, for in the Anthropoidea the stapedial branch of the artery is wholly wanting. The canal pierces the bulla in its posterior moiety, and passing forward over the cochlea, enters the cranial chamber in the middle or cerebral fossa, near the posterior clinoid process, just in advance of the tentorial ridge. This is evidently a superior

arrangement to that seen in *Lemur* and *Propithecus*, for the reason that the blood is delivered more directly to that part of the brain which it is intended to supply.

The following variations in the position of the external opening of the canal may be noted: In *Tarsius*, figure 103, it is placed a little anterior to the external auditory meatus and

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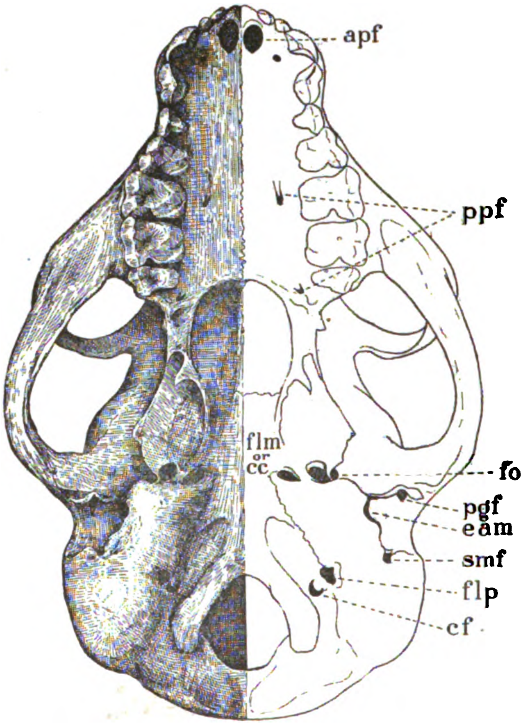

FIGURE 102.—View of the base of the skull of *Galago Monteiri*.

apf, anterior palatine foramen; *ppf*, posterior palatine foramina; *fo*, foramen ovale; *flm* or *cc*, foramen lacerum medium or carotid canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *smf*, stylomastoid foramen; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

rather to the outer than to the inner side of the bulla; in *Hapale* it is opposite the middle of the external auditory meatus upon the inner side of the bulla; in the Cebidæ, figure 104, it is yet more internal and somewhat more posterior;* and

* In *Hapale* and *Nyctipithecus* an interesting variation occurs. The main artery pierces the bulla in its usual position, but it apparently gives off a considerable branch, which enters the cranial chamber through a canal between the bulla and the basioccipital. This results in an arrangement similar to that found in *Lemur* and *Propithecus*, except that the position of the main branch is reversed.

in the Old World monkeys and the Anthropoids it has practically the same position as in the human species. In the extinct Eocene apes, as far as known, the main canal pierces the bulla in its posterior external portions. It should be here noted, also, that the relative size of the canal steadily increases from the small-brained to the large-brained forms, and that

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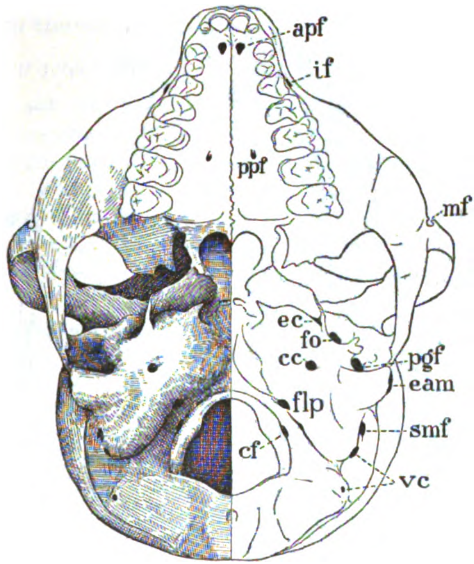

FIGURE 103.—Basal view of the skull of *Tarsius spectrum*; enlarged.

apf, anterior palatine foramen; *if*, infraorbital foramen; *ppf*, posterior palatine foramen; *mf*, malar foramen; *ec*, eustachian canal; *fo*, foramen ovale; *cc*, carotid canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *smf*, stylomastoid foramen; *vc*, venous canals; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.

this increase is directly proportioned to the degree of development of the cerebral hemispheres.

There yet remain to be described other characters of the blood supply to the brain through the vertebral arteries, in certain groups of the Primates, which are of importance from the standpoint of classification. In the lemurs,* the New World, and a few of the Old World monkeys, the course of the artery through the transverse process of the atlas is somewhat different from that seen in *Tarsius*, the anthropoid apes, and man. If the atlas of an anthropoid ape or man is viewed from behind, the large vertebrarterial canal will be

*The only exception which I have been able to find in this group is *Perodicticus potto*, in which the anterior bony bridge is not quite complete.

seen perforating the transverse process at its junction with the lateral mass of the bone. The anterior continuation of this canal is a deep groove turning sharply upward to reach a second perforation or deep notch in the anterior edge of the superior arch, at the upper extremity of the oval cup-shaped cotylus. This latter notch or foramen is known as the *sinus atlantis*, and serves for the entrance of the vertebral artery

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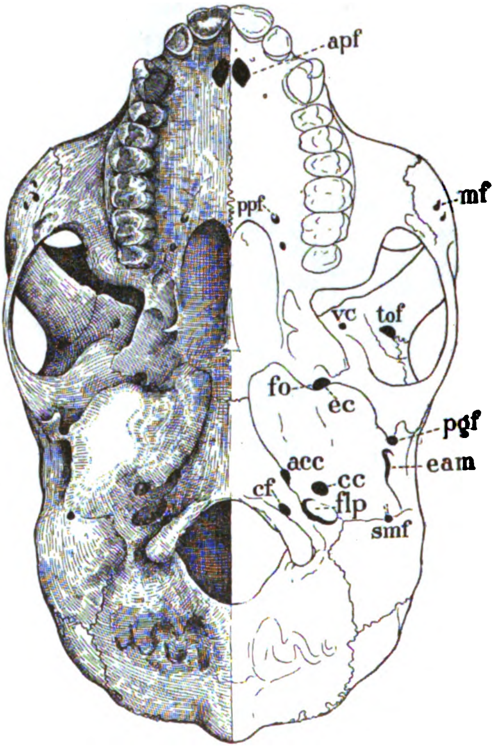

Figure 104.—Basal view of the skull of *Nyctipithecus felinus*.

***apf*, anterior palatine foramen: *ppf*, posterior palatine foramen; *mf*, malar foramen; *vc*, venous canal; *tof*, temporo-orbital foramen; *fo*, foramen ovale; *ec*, eustachian canal; *pgf*, postglenoid foramen; *eam*, external auditory meatus; *acc*, accessory carotid canal; *cc*, carotid canal; *smf*, stylomastoid foramen; *flp*, foramen lacerum posticum; *cf*, condyloid foramen.**

and the exit of the first spinal or suboccipital nerve. Now, in the lemurs and lower monkeys, a strong bony bridge is thrown forward from the transverse process to the upper extremity of the cotylus, so as to cover in that part of the canal or groove where it turns sharply upward, and give separate openings for the superior and inferior (anterior and posterior of anthro-

potomy) divisions of the suboccipital nerve. This difference in the arrangement of the canal is constant and well marked, and serves as a reliable guide for distinguishing certain of the groups. The latter condition is also found in the Insectivora, and may be therefore looked upon as the more primitive of the two.

Finally, I may mention the absence of a separate opening *(foramen spinosum)*, for the entrance of the middle meningeal artery into the cranial cavity, in all Primates except man.

Characters of the Prehensile Extremities.

The second set or group of characters of fundamental importance, by means of which the Primates are distinguished from all other orders of the Mammalia, relates to the modification of the hands and feet into more or less perfect prehensile or grasping organs, and in this respect they stand sharply apart from all other divisions of Eutherian mammals. Of the causes which led to this modification, very little is known, but there can be hardly any doubt that it was one of the primary distinguishing features of their remote Metatherian ancestors far back in the Mesozoic, and that its appearance constituted one of the first steps which led to their subsequent differentiation into such a distinct group. The particular type of extremity from which the prehensile modification arose was undoubtedly that of the plain plantigrade condition; and the assumption of an arboreal manner of life, we may readily believe, was the all-important determining factor in its evolution.

Exclusive of man, the Primates are, without exception, the most preëminently arboreal in habit of all the Mammalia. The arrangement of the thumb and great toe in opposition to the other digits, thus making it possible to take a firm hold or grasp upon the branches of a tree, is one of vast superiority to that in which the digits depend for their effectiveness upon sharp claws.

In the latter case, the claws serve as so many hooks by means of which the weight of the body is sustained in the act of climbing, whereas in the prehensile hand or foot of the Primates the hold is rendered effective by the opposability of certain of the digits to each other. The advantage of the grasping extremity over that which is solely dependent upon the hooked claws is seen in the ability of the animal possessing the former to traverse the forest without descending to the ground. Where the large branches of the adjoining trees interlace, the clawed animal experiences little difficulty in passing from one to the other, but if the trees are scattering, so that only the small branches touch, his progress is barred. To the animal with prehensile extremities, however, the case

is different; he simply runs out until he can gather a handful of smaller branches of the opposite tree, and swings himself across the interval with ease. Indeed, the skill displayed by monkeys in climbing surpasses that of any other animal.

It is of course not now possible to discover just what combination of circumstances first led the ancestors of the Primates to adopt an arboreal habit; it may have been for the purpose of greater protection from enemies, it may be that certain kinds of food, such as fruit and nuts, attracted them to the trees, or it may have been both; but, whatever the cause, it appears certain that this manner of life was adopted very early in their career, and has been responsible for one of the most important structural modifications which they now exhibit.

Another matter of great interest in connection with the prehensile extremities relates to their probable influence upon the growth of the cerebral hemispheres, as well as the general increase in intelligence in the Primates. No very complete phyletic history can as yet be made out for any existing species of monkeys, but such evidence as is obtainable demonstrates very clearly that the brain has increased in size over and above that found in the earliest forms. In some instances, this increase has been less marked than in others, but there has been, nevertheless, a gradual development of the cerebral hemispheres in all groups of the Primates. In the case of the lemurs the increase has been comparatively small, while in the apes and monkeys it has been relatively great.

Now, to what causes is it possible to attribute this development of the brain? A few modern naturalists of note claim to have discovered evidence of an internal perfecting or directing principle, by means of which variations along a given line only are originated and preserved, and which, through the subsequent action of natural selection, forever holds them steadfast in the narrow path of their final development. In any such view of evolution, I find it necessary to express my utter and unqualified disbelief. In my judgment, not only is there no evidence in support of such a proposition, but, on the contrary, all the facts of paleontology, as far as they are capable of any interpretation, point directly to an opposite conclusion. Such a view of evolution, moreover, presents no advantages over the antiquated doctrine of special creation, which, on account of its inconceivability as well as of total lack of evidence in its support, has long since been relegated to the category of extinct ideas.

In like manner do I find it equally difficult, and inconsistent with the evidence, to believe in the all-sufficiency of natural selection, as advocated by the Neo-Darwinian school of evolutionists. If we had no evidence other than that afforded by the well-known modifications in structure of the cave faunæ

upon which to rest our belief in certain factors concerned in evolution, we could yet feel reasonably assured that the inherited effects of disuse had played no unimportant part in the retrogressive changes which these animals have suffered in the past.

According to the very able researches of Packard and Eigenmann, the loss of sight as well as other important changes in these cave forms can be explained on no other rational hypothesis than that of *the inherited effects of disuse;* and while the admission of such explanation, as a fact, may render impossible the construction of a satisfactory theory of heredity, in the light of our present knowledge, then all that can be said is, so much the worse for a theory of heredity.* If, therefore, the inherited effects of disuse are capable of producing such profound modifications as those to which reference has just been made, it follows that the inherited effects of prolonged *use* must have been equally potent in the production of change in animal structure. This, I may say, is the kind of evolution that was taught by the great master minds who gave it birth, and, notwithstanding all the subsequent discussion which has taken place regarding the factors concerned in the process, I am still firmly of the opinion that the theory of evolution, as set forth by Darwin and Huxley, comes nearer to the truth than all others yet advanced.

With this understanding of the nature of the causes by means of which we must, in my judgment, seek to explain the progressive changes in brain structure among the Primates, we are now prepared to return to the inquiry.

It is first necessary to recall that different species of animals seem to employ the special senses in different degrees, for the purpose of acquiring information of any object that may excite their attention. Among such animals as our domestic horse and cow, if confronted by any object new or strange to them, they will at once give evidence of the fact by every attitude of marked attention. If not sufficiently frightened to run away, they proceed to inspect it from every point of vantage. Sight alone, however, seems to be insufficient to satisfy their curiosity or allay their suspicions, and it is not until they are able to approach near enough to test it fully by the sense of smell that they seem to be able to acquire the necessary information they desire. This same characteristic of depending largely upon the sense of smell is true of many animals in a state of nature. It is quite as much by this means as by the sense of sight that they detect danger.

As among the hoofed animals, the Carnivora also depend largely upon sight and smell for information. In rare instances, the dog will use his paw for the purpose of turning an object

* For the evidence in favor of the transmission of acquired characters, see also the works of Hyatt, Ryder, Cope, Beecher, and others.

over, so that he may inspect it more closely, and the raccoon and bear do this more frequently, but the lack of opposability of the thumb places great difficulties in the way of handling an object to any considerable extent.

Among the monkeys, on the other hand, information of a strange or suspicious object is obtained by sight, at first always at a respectful distance. If the animal is assured that no imminent danger threatens, he will cautiously approach for closer scrutiny; if harmless, he soon takes the object in his hands and inspects it carefully upon all sides. If there is any internal mechanism to excite curiosity, it is forthwith pulled in pieces or broken, in order that every part may be examined attentively. It is only in case of an article of food that he uses his sense of smell. In this extensive use of the hands, the monkey exhibits traits and capabilities for the acquisition of knowledge far in advance of all other mammals. Not only is there great curiosity, but an active desire for information of all things new or strange in his surroundings. The undisputed testimony of many excellent observers could be quoted in support of this assertion, but the facts are so well known that it is scarcely necessary.

That which interests us most in this connection is the extent to which the animal makes use of the prehensile extremities in acquiring information and satisfying curiosity. There can be little doubt that, as in man, the sense of sight is the source from which the greatest amount of information is derived; but at the same time the ability to pick up, handle, and closely inspect any object,—possible only with prehensile extremities,—has constituted a most powerful aid in acquiring knowledge of the smaller details. The constant action and reaction of this process, with its inherited effects, upon the brain, throughout innumerable generations, we may readily believe, have resulted in an ever widening circle of psychic activity and cerebral development.

Another factor which may have had its share in the process is the particular way in which the brain has received its supply of blood from the heart. As we have already seen, the arrangement of the entocarotid circulation is different in monkeys, apes, and man, from that found in the lemurs. In one group of the lemurs, the blood through the entocarotid is carried directly to the base of the skull, where the artery enters the middle or cerebral chamber. In another group, the blood is delivered into the posterior chamber of the skull through a foramen alongside the otic bulla, or ear pouch. In monkeys and man, the entocarotid pierces the petro-tympanic, and delivers the blood directly to the base of the brain in the middle chamber. As far as directness of supply is concerned, the

arrangement found in one section of lemurs appears to be as advantageous as that of monkeys and man, and upon any hypothesis which involves this blood supply through the entocarotids, the brain of these forms of lemur should have developed as rapidly as that of the monkeys.

The explanation of this seeming inconsistency, I apprehend, is to be found in the relative importance of the two sets of arterial feeders of the cerebral hemispheres; viz., the entocarotids and vertebrals. The latter, it should be remembered, lie deeply in the neck and pursue a somewhat tortuous course through the foramina of the neck vertebræ, finally uniting on the floor of the posterior chamber of the skull to form the basilar artery. From this trunk, a pair of arteries is given off, which diverge and pass forward along the floor of the middle chamber, to unite with the entocarotid branches, forming, in conjunction with an anterior connecting branch, the circle of Willis. From the union of the entocarotid with the anterior branch of the basilar springs a large artery which passes upward through the fissure of Sylvius, and gives the principal supply of blood to the cerebrum.

In monkeys and man, the vertebral branches are relatively small and insignificant, and the entocarotids correspondingly large. In the lemurs, on the other hand, this condition is reversed; the vertebrals are large and the entocarotids small. In the one case, the entocarotids became the predominant feeders of the cerebral hemispheres, and there was corresponding increase in size and a general increase in intelligence; in the other, this office was performed largely by the vertebrals, and the brain developed more slowly. It is evident that the advantage lay on the side of the more direct current, which must have resulted in giving a greater stimulus to the psychic activities of the monkey, and have been responsible for his evolution in this direction.

Having now stated the probable relationship which must have existed almost from the very beginning between the development of the cerebral hemispheres, the prehensile extremities, and the carotid circulation, I proceed next to an examination of the skeletal structure of the manus and pes, in which the osseus index of some of these conditions above described is plainly exhibited. Selecting one of the more typical representatives of the order, the chief osteological characters of the hand and foot may be briefly stated as follows:

The Pes.—When the four outer digits are made to rest upon a plane surface, the tibial facet of the astragalus looks almost directly inward, while the fibular facet looks upward and a little outward.* The head of the astragalus is obliquely

* These two characters do not apply to the human foot, which has been modified for terrestrial progression in the erect position.

placed and is much rounded; the tuber of the calcaneum is short and incurved; the cuboid is high, broad from side to side, and of comparatively little dorso-palmar thickness; there are never less than five digits, and with the exception of the marmosets and man, the hallux is always opposable; the metatarsals are slightly interlocking, and their distal extremities, exclusive of the hallux, display a characteristic pattern, compressed from side to side, much rounded from before backward, and with progressive disappearance of keels, grooves, and sesamoids of the flexor tendons; the phalanges are elongate and curved, and the unguals are in various stages of transition from claw to nail; the distal extremity of the metatarsal of the hallux is always provided with sesamoids, and has a distinct keel and grooves; its opposability is shown by its deeply excavated proximal extremity and the convex surface of the internal cuneiform, and its terminal phalanx is always flattened and nail-like.

The Manus.—The manus has the power of complete pronation and supination; the carpus is relatively high and narrow, and its proximal articular surface is much arched from side to side; the unciform and magnum have great relative height, and a centrale may or may not be present; the metacarpals have characteristic globular extremities, in which the keels, grooves, and sesamoids are little developed, and disappear completely in the higher forms; the phalanges are elongate, and the unguals may be compressed and clawlike or depressed and nail-like; the pollex is very generally present and, with the exception of the marmosets and some lemurs, is always opposable and nail-bearing; its opposability, like that of the hallux, is indicated by the character of its articulation with the trapezium.

The chief characters of the other parts of the skeleton are the following: The teeth have brachyodont crowns with low rounded cusps; the incisors are very generally reduced to two above and below, but exceptionally may be two above and one below (*Tarsius*), or, again, one above and below, with rodent-like modification (*Mixodectes*, *Microsyops*, *Metacheiromys*, and *Cheiromys*); the premolars rarely become molariform, but progressively decrease in number to two above and below; the orbit, except possibly in a few instances, is always encircled by bone posteriorly, the orbital and temporal fossæ are separated by a bony partition in the higher forms, and the eyes are directed forward; the mandibular rami are early coössified in the more advanced species; the limbs are elongate and well developed, and clavicles are always present; the coracoid is large, the olecranon is short, and the fibula is very generally unreduced; the astragalus is without an astragalar foramen.

[To be continued.]

ART. XVI.—*On Ceric Chromate;* by PHILIP E. BROWNING and CHARLES P. FLORA.

[Contributions from the Kent Chemical Laboratory of Yale University—CXIV.]

BÖHM* in a recent paper descriptive of his thorough investigations of the application of chromic acid to the separation of the cerium earths, states that when the mixed oxides of cerium lanthanum and didymium are brought in contact with a calculated amount of chromic acid, a little water added, and heat applied for a time, an orange red amorphous powder remains which proves to be a basic ceric chromate. In connection with a study of the methods of separating the cerium earths, begun last summer, we had occasion to make an experiment similar to that described by Böhm, differing possibly in this respect, that we used a decided excess of the chromic acid (100 grms. of the oxides with 150 grms. of chromic acid and 200^{cm^3} of water).

The product which we obtained was a bright scarlet crystalline salt, which, when washed sparingly with water and dried over sulphuric acid, became a little darker in color but retained its crystalline condition. Examined under the microscope the salt appeared homogeneous, and the crystalline form orthorhombic, the prevailing habit being prismatic, $m \wedge m'''$, $110 \wedge 1\bar{1}0$, being approximately 58° C. The macropinacoid, *a* (100), is generally present, the brachypinacoid, *b* (010), is well developed, and a flat brachydome and the basal plane, *c* (001), are the terminating forms. The crystals are etched or pitted, are slightly pleochroic, and exhibit parallel extinction and low birefringence. When treated with water the salt loses chromic acid and becomes an orange yellow. It may be heated to about 150° C. without loss of weight. Between 150° and 180° C. it loses water and becomes brownish red, still retaining much the same original exterior form. Above 180° C. it decomposes. It is quite readily soluble in dilute acids, especially sulphuric acid, and is easily decomposed by potassium or sodium hydroxide into the alkali chromate and ceric hydroxide. The ceric hydroxide thus formed is quite readily soluble in acids and promises to be a convenient starting point for the preparation of ceric salts. Qualitative tests proved the absence of both yttrium and didymium.

Analysis of the salt gave the following results: Five closely agreeing determinations of water, six determinations of ceric oxide, among which the greatest variation was about one per cent, and sixteen determinations of chromic acid showing as the greatest variation about two per cent, gave the averages tabulated below:

* Zeitschr. angew. Chem., xv, 1282.

Salt examined.		$Ce(CrO_4)_2 2H_2O$ calculated.	
CeO_2	41·94	CeO_2	42·14
CrO_3	49·61	CrO_3	49.04
H_2O	8·82	H_2O	8·82
	100·37		100·00

From these analyses we feel justified in assuming the crystalline salt to be a close approximation to a compound whose constitution would be expressed by the symbol $Ce(CrO_4)_2 \cdot 2H_2O$.

The material from which the mixed oxides used in this work were obtained was a mixture of sulphates of cerium lanthanum and didymium, carrying a trace of yttrium.

The authors are indebted to Mr. J. C. Blake for the crystallographic examination.

ART. XVII.—*The Effects of Changes of Temperature on Permanent Magnets;* by HIRAM B. LOOMIS.

THE following paper is an account of some experiments undertaken to determine more accurately, if possible, the kind of change which takes place when a magnet is heated and cooled after it has been brought to the "permanent state." The subject will be considered under the following heads: I. Historical Sketch. II. Experiments and Calculation of Results. III. Discussion of Results.

I. *Historical Sketch.*

A. *Investigations on the change in magnetic moment due to change in temperature.*—About 1825, Kupfer* magnetized a steel bar and placed it in a water bath at the temperature of the room. Near it he suspended a magnetic needle and determined the period of 300 swings. The bath was then heated to 100 C. and the period of 300 swings was again determined. The bar was then alternately heated and cooled between these limits of temperature and similar observations taken. Kupfer thus learned that if a permanent magnet is heated above its temperature of magnetization its magnetic moment decreases, that on again cooling the moment increases but not enough to make up for the first loss, and that this is true for the first three or four times it is heated and cooled.

In 1851, Lamont† found that when a permanent magnet was alternately heated and cooled fifteen or sixteen times between fixed limits of temperature, it reached a permanent state in which it had a definite magnetic moment for a given temperature, to which it always returned when brought to that temperature, provided only it had never passed beyond the temperature limits mentioned above. The higher the temperature, the smaller was the magnetic moment.

Riess and Moser‡ also experimented on the change in magnetic moment by swinging magnets in the earth's field and determining the period of vibration. For needles 34 lines long they found the following formula held:

$$I' = I\,[1 - 0{\cdot}000324\,(t'-t)d],$$

in which I and I′ are the intensities of magnetization at the temperatures t and t' on the Reaumur scale, and d is the diameter of the magnets. For needles two inches long the numerical factor is 0·000432, showing that the proportional change in intensity of magnetization is greater in shorter magnets.

* Wiedemann's Electricität, iii, p. 753.
† Lamont, Pogg. Ann., lxxxii, p. 440, 1851.
‡ Riess and Moser, Pogg. Ann., xvii, p. 425, 1829.

The temperature limits were 0° and 80° R. By swinging their magnets at different temperatures they found the change in moment proportional to the difference in temperature, as is shown by their formula.

Prof. G. Wiedemann* has made some careful investigations on the influence exerted by the temper of the steel and the original intensity of magnetization. He used bars 22^{cm} long and $1·35^{cm}$ in diameter. Before they were magnetized these bars were placed alternately in melting snow and boiling water fifteen times, in order to bring the steel itself as far as possible into such a state that alterations in temperature would produce no structural change. The bars were magnetized in a coil at a temperature of 0° C. They were then carefully placed in a box of sheet copper before the needle of a magnetometer and the deflection was observed by telescope and scale. The temperatures of 0° and 100° C. were obtained by means of melting snow and boiling water. His results for magnets that have reached the permanent state show that in case of hard steel magnets the change in moment is nearly proportional to the moment at 0° C., while for tempered and soft steel magnets, the ratio of change to the moment at 0° C. increases with the moment. As his results give a good idea of the size of the changes under discussion, I append the following table from his paper.

With reference to the theory of these changes Prof. Wiedemann says: "Besides the permanent effect due to an alteration in temperature there is a temporary change. Each heating diminishes the permanent moment of the molecules. Moreover, for the time being, it loosens the particles of the body and lessens the strain in which they have been placed by the action of external forces, therefore they return a little toward their first position of equilibrium, in which they were held by the forces acting between them before the external forces came into play. Heating thus diminishes the magnetization temporarily; but, on cooling, the molecules return to their former position and the lost magnetization is regained. We can produce entirely analogous phenomena if we change the temperature of bodies which have suffered a change of form (torsion) as a result of mechanical forces, and observe the increase and decrease of this on heating and cooling."

Barus and Strouhal† carefully distinguished the mechanical effect of heating from the purely magnetic effect. They found that a temperature of 20° or 30° C. above that of the water in which a glass-hard steel rod was dipped in hardening produced quite perceptible annealing effects. This change in the hard-

* G. Wiedemann, Pogg. Ann., c, p. 235, 1852; ciii, p. 563, 1858; cxxii, p. 355, 1864.

† Bull. U. S. G. S., No. 14, p. 151.

M_0	M_{100}	M'_0	N_0	N_{100}	$\frac{M_0-M_{100}}{M_0}$	$\frac{M_0-M'_0}{M_0}$	$\frac{M_0-N_0}{M_0}$	$\frac{N_0-N_{100}}{N_0}$
				I. *Hard steel bar.*				
71·5	41·5	44·8	37·	33·2	0·420	0·373	0·483	0·103
134·5	89·2	96·	85·5	77·8	0·321	0·286	0·364	0·090
195·	134·3	146·2	133·3	120·	0·311	0·250	0·316	0·100
				II. *Tempered steel bar.*				
44·	27·	30·	29·	27·	0·386	0·318	0·341	0·0690
148·5	107·2	114·5	110·3	101·	0·278	0·229	0·257	0·0814
219·5	165·	179·	172·	156·	0·249	0·184	0·216	0·0930
317·	239·	260·7	251·2	226·	0·246	0·178	0·207	0·1003
				Soft steel bar, No. 1.				
85·	45·		38·	33·2	0·471		0·553	0·126
141·	73·5		68·5	57·	0·479		0·514	0·168
193·	99·		101·	78·5	0·487		0·478	0·223
209·5	109·5		115·	88·2	0·477		0·451	0·233
				Soft steel bar, No. 2.				
95·5	49·7	54·2	45·	39·	0·479	0·432	0·529	0·133
136·5	73·	81·5	69·	59·	0·465	0·403	0·495	0·145
174·8	92·5	108·3	93·4	76·	0·471	0·378	0·466	0·186
				Very soft steel bar which had been heated and slowly cooled many times.				
51·5	34·5	37·			0·330	0·282		
80·5	54·5	58·			0·323	0·279		
113·	76·	82·			0·328	0·274		
159·5	103·3	116·5			0·353	0·270		
181·	113·5	131·			0·373	0·277		

M_0 is the intensity of magnetization before any change in temperature has taken place; M_{100}, when first heated to 100° C.; M'_0, after being again cooled to 0° C. N_0 and N_{100} are the intensities of magnetization at the temperatures indicated by the subscripts after the magnet has been heated and cooled fifteen times.

ness of the steel would naturally affect the magnetization. According to their experiments, if a glass hard steel rod is thoroughly annealed by being kept at the temperature of boiling water for a day or two and then magnetized to saturation at the temperature of the room, the loss in magnetization on being heated to the boiling point is relatively small and is nearly independent of the time it is kept there. Nearly the whole change takes place during the first ten minutes. On the other hand, if the bar is not first annealed, the change is much larger and is not complete after twenty-two hours heating.

B. *Investigations on the effect of change of temperature on*

the distribution of magnetism.—Kupfer* determined at two different temperatures the period of vibration of a short needle placed opposite different parts of a long magnet and found the proportional change in distribution greater at the ends than in the middle of the bar. All his measurements were made before the bar had reached the permanent state.

Poloni† measured the distribution at various temperatures, by slipping a coil from different parts of the magnet to such a distance that the magnet exerted practically no effect and measuring the quantity of electricity thus induced. He worked between the temperatures 0° and 200° C., using an oil bath to obtain his high temperatures. The changes were quite regular between 0° and 180° C., but were very large near 190° C. Between 0 and 180 C., he found that the following formula held:

$$M = A[1 + k^{-l} - k^{-x} - k^{(l+x)}]$$

in which M is the induction in the magnet at a distance x from one of the ends; l, the length of the magnet; A, a quantity depending only on the temperature, while k is sensibly constant for a given magnet.

II. *Experiments and Calculation of Results.*

The existence of a permanent state, in which the moment of a magnet increases or diminishes as its temperature falls or rises, being now well established, the reason for this change becomes an interesting subject for investigation. In the hope of obtaining some clue to its real nature, the following experiments were undertaken. They were planned to determine: first, the change in magnetic moment due to change in temperature in bars of the same cross-section but of different lengths; second, the change in distribution due to change in temperature. The experiments will be considered in the above order.

A. *Experiments on the change of the magnetic moment of magnets of different lengths but of the same cross-section.*—Stubb's steel wire of square cross-section, $0{\cdot}159^{cm}$ square, was cut into lengths of approximately $5{\cdot}5^{cm}$, $8{\cdot}3^{cm}$, and 22^{cm}. The steel was soft and was used of the same temper as purchased. The bars were annealed in boiling water, magnetized to saturation in a coil, and were in the permanent state when used. The period of vibration in the earth's field was determined at 11° and 99° C. A double box of thin sheet zinc was used to keep the magnets at the required temperatures. In the top of the box was a round opening into the interior, in which a cork holding a thermometer and a glass tube was inserted. Through this tube passed a short wire, which supported the magnet and was suspended from the ceiling by cocoon silk. The suspen-

* Kupfer, Pogg. Ann., xii, p. 133.
† Poloni, Beibl. v, 802. Atti della R. Acad. dei Lincei, v, p. 262, 1881.

sion was thus quite long and was but little exposed to the action of the heat. The bulb of the thermometer was close to the magnet. In the side of the box was another opening, covered with glass, through which a mirror attached to the magnet was observed, and the time of vibration thus determined. The temperature of the space in which the magnets swung was kept quite constant at 11° C. or 99° C., by passing a current of cold water or steam through the space between the two parts of the double box. For the lower temperature city water was used direct from the faucet.

The magnets and the mirror used in observing their vibrations were weighed. The lengths of the magnets were measured at the ordinary temperature of the room, 18° C. The corrected lengths for 11° and 99° C. were obtained by the following formulæ:

$$L_{11} = L(1 - 7 \times 0{\cdot}000011),$$
$$L_{99} = L(1 + 81 \times 0{\cdot}000011),$$

in which L_{11} and L_{99} are the lengths at the temperatures indicated by the subscripts, L is the observed length, and 0·000011 is the coefficient of linear expansion of untempered steel. The moments of inertia for the magnets at each temperature were calculated as follows:

$$I_{11} = m\frac{L_{11}^2 + b^2}{12},$$

$$I_{99} = I_{11}\frac{L_{99}^2}{L_{11}^2},$$

in which m is the mass of the magnet and b its thickness. The mass of the mirror and of the appliances by which it was fastened to the magnet was 0·4245 grms., and calling its radius of gyration $0{\cdot}2^{cm}$ the moment of inertia due to it was 0·0170, which was added to that of the magnets. No correction was made for the rest of the suspending apparatus; its mass was always less than 0·10 grms., and it consisted principally of a piece of fine wire about 25^{cm} long; and its radius of gyration was exceedingly small, being a fraction of the diameter of the wire. The silk suspension was about 3·5 meters long. No allowance was made for the effect of torsion, as the magnet could be turned 360° without producing enough difference in azimuth to be detected by a telescope and scale at a distance of 3 meters. The formulæ for the magnetic moments are:

$$M_{11} = \frac{4I_{11}'\pi^2}{T^2H}, \qquad M_{99} = \frac{4I_{99}'\pi^2}{T^2H},$$

in which I′ denotes the total moment of inertia of the system at the temperature indicated: T, the period of a complete vibration; and H, the horizontal intensity of the earth's magnetic force. H was taken as equal to 0·2. It has been deter-

mined by several previous observers in the room in which the work was done; and as there were no local disturbing iron masses, that part of the building being kept free from iron, it may be taken as within one half of one per cent of correct.

Specimen Calculation.—Magnet No. 9.

Length at 18° C.	$16{\cdot}40^{cm}$
Mass	$3{\cdot}609^{grms}$
Period of vibration at 11° C.	$10{\cdot}435^{sec}$
Period of vibration at 99° C.	$10{\cdot}812^{sec}$
$L_{11} = 16{\cdot}40\,(1 - 7 \times 0{\cdot}000011)$	$16{\cdot}399^{cm}$
$L_{99} = 16{\cdot}40\,(1 + 81 \times 0{\cdot}000011)$	$16{\cdot}414^{cm}$
$I_{11} = m\,\dfrac{L_{11}{}^2 + b^2}{12} = \dfrac{3{\cdot}609\,(268{\cdot}92 + 0{\cdot}02)}{12}$	$80{\cdot}883$
$I_{99} = I_{11}\,\dfrac{L_{99}{}^2}{L_{11}{}^2} = 80{\cdot}883\,\dfrac{269{\cdot}43}{268{\cdot}91}$	$81{\cdot}034$
$I_{11}{}' = 80{\cdot}883 + 0{\cdot}017$	$80{\cdot}900$
$I_{99}{}' = 81{\cdot}034 + 0{\cdot}017$	$81{\cdot}051$
$M_{11} = \dfrac{4I_{11}{}'\pi^2}{T_{11}{}^2 H} = \dfrac{4 \times 80{\cdot}9 \times 9{\cdot}8696}{108{\cdot}889 \times 0{\cdot}2}$	$146{\cdot}64$
$M_{99} = \dfrac{4I_{99}{}'\pi^2}{T_{99}{}^2 H} = \dfrac{4 \times 81{\cdot}051 \times 9{\cdot}8696}{116{\cdot}899 \times 0{\cdot}2}$	$136{\cdot}80$

The results of this series of experiments are given in the following table: and figure 1 gives a curve in which $\dfrac{M_{11} - M_{99}}{M_{11}}$ is platted as a function of the intensity of magnetization.

Magnets of Square Cross-Section. ($0{\cdot}159^{cm}$ square).

Number of magnet.	Length of magnet.	Moment at 11° C. M_{11}	Moment at 99° C. M_{99}	$\dfrac{M_{11}-M_{99}}{M_{11}}$	Intensity of magnetization.
3	21·53	232·92	219·88	0·056	427
5	22·00	207·08	193·64	0·065	372
9	16·40	146·64	136·80	0·067	352
15	16·31	139·76	129·28	0·075	338
4	11·23	94·76	88·04	0·071	333
6	10·80	72·41	65·72	0·092	249
7	8·15	43·04	38·48	0·105	208
8	8·17	40·48	35·92	0·112	196
13	5·49	16·72	14·44	0·141	117
12	5·40	12·04	9·84	0·220	88

B. *Experiments on the change in distribution due to change in temperature.*—The apparatus employed was suggested by the late Prof. Henry A. Rowland, under whose direction the investigation was conducted, and will be best understood from the diagram in fig. 2. A and B are two cylindrical soft steel magnets (Stubb's steel of the same temper as when purchased) $30{\cdot}1^{cm}$

long, and 0·55^{cm} in diameter. They were magnetized to saturation in a coil, the magnetic circuit being completed by an iron casting of suitable size and shape. They were then brought to the permanent state by alternate heating and cooling. In both ends of each, holes were bored and threads cut. The depth of these holes in magnet A was 8^{mm} at each end. In magnet B

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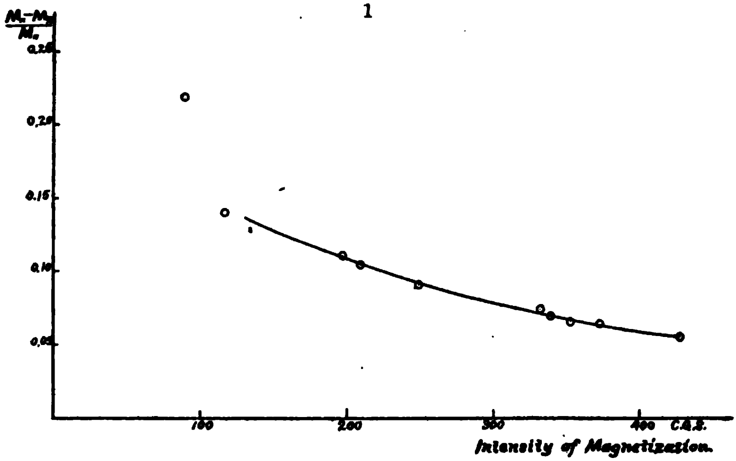

the hole at the south end was 11^{mm} deep; that at the north end 7^{mm}. In the experiment the magnets were placed perpendicular to the earth's field. Pieces of brass rod, H,H,H,H, of the same diameter as the magnets were screwed into their ends and acted as guides for the two coils (to be described presently), so that after the coils had been slipped off the magnets, they could be slipped back again without trouble. DD is a brass

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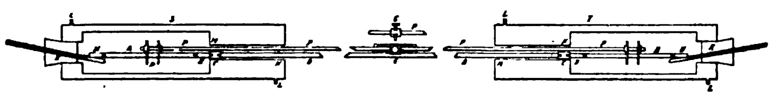

rod about 1·5 meters long, holding two magnets together in the position shown in the figure. C,C are pieces of non-conducting material to keep the magnets from changing temperature by conducting along the rod DD. E and F are two coils of very fine wire wound on paper tubes which just fit the magnets. They consisted of 150 turns (five layers of 30 turns each), and were about 7^{mm} wide. Their frames were joined by a brass rod, PP, of such length that when the coil E was at the center of the magnet B, the coil F was also at the center of the magnet A. By means of this rod they could be moved simultaneously over corresponding portions of the two magnets. At G is a gauge which regulates the distance the coils are moved at a time, so that as they are moved step by step from one end of

the bar to the other, the steps will be of equal length. By loosening a screw the coils may be moved from the middle of the magnets to either end at one step. The cross-sections of two cylindrical double boxes, made of sheet zinc, are indicated at S and T. At K,K are openings in which corks holding thermometers were inserted. At L,L are openings into the spaces between the two parts of the double boxes. Through these a current of steam or cold water was passed to keep the space containing the magnets at the requisite temperature. The temperatures employed were 14° C. and 99°·5 C. City water direct from the faucet was used to produce the lower temperature, and a fairly constant temperature was easily maintained. NM,NM, are other openings by which the magnets were introduced and through which the bars DD and PP passed. They were about $2{\cdot}5^{cm}$ in diameter and 20^{cm} long, and were stuffed with cotton, the better to maintain the temperature of the interior. The exploring coils were connected up with an ordinary astatic galvanometer of rather low resistance in such a way that the currents induced by moving them along the magnets opposed each other. An earth inductor and a resistance box were included in the circuit, and in each experiment the galvanometer readings were standardized by the earth inductor. Beginning at the middle of the magnets, the coils were moved step by step to one end, the throw of the needle being observed for each step. The coils were moved so far in the last step that practically no lines of induction passed through them, as was determined by experiment. Similar observations were made for the other half of the magnets. In this way was measured the excess of the number of lines of induction passing from a certain section of one magnet into the air over that passing out of the corresponding section of the other magnet, thus giving the difference of distribution in the two magnets. These measurements are taken first when A and B are both at 14° C., and again when A is at 14° C. but B at 99°·5 C. The difference between the two sets after they have been reduced to the same scale by the earth inductor readings is evidently the change in distribution in B due to the change in temperature. By this method the quantity observed is of about the same magnitude as the quantity we desire to obtain; the greatest throw of the needle was but little over twice the largest difference obtained on subtracting the two sets of observations.

To get the distribution of magnetism of the bars, the difference in distribution was first measured as above indicated, then the connection of the coils was changed so that the currents induced in the two coils were in the same direction, and the sum of the distributions was obtained in the same way. In

this case extra resistance had to be added from the resistance box to keep the readings on the scale.

Calculation of Results.

The formula for the ballistic galvanometer is

$$Q=k \sin \frac{\theta}{2}$$

in which Q is the quantity of electricity; k, a constant factor; and θ, the angular throw of the needle. The observations were made with telescope and scale. Letting d represent the observed throw and r the distance of the mirror from the scale,

$$\tan 2\theta = \frac{d}{r}$$

Expanding $\sin \frac{\theta}{2}$ we have

$$\operatorname{Sin} \frac{\theta}{2} = \frac{d}{2r}\left[1-0{\cdot}344\left(\frac{d}{r}\right)^2 + \right]$$

This formula was used in reducing the large readings.

The earth inductor readings were taken frequently and varied but little throughout the experiment. The throw due to the earth inductor when both magnets were at 14° C. was 39·5 scale divisions; when one magnet was at 99°·5 C. and the other at 14° C., it was 37·8. Corresponding throws of the needle due to the slipping of the exploring coils over various portions of the magnets were averaged. The average throws taken when one magnet was hot and the other cold was multiplied by $\frac{39{\cdot}5}{37{\cdot}8} = 1{\cdot}045$ to reduce to the same scale as the readings taken when both magnets were at 14° C. Correspondings measurements were then subtracted to get the difference of distribution caused by change in temperature in terms of the scale divisions. The reduction to absolute measurement was as follows: The effective area of the earth inductor, as determined by previous observers, was $20{,}716^{\text{sq cm}}$. The total number of lines of induction cut by turning the earth inductor was $2HA=8{,}286{\cdot}4$. The throw was 39·5 scale divisions, therefore each scale division of throw caused by the movement of the exploring coils corresponded to $8{,}286{\cdot}4 \div (39{\cdot}5 \times 150) = 1{\cdot}398$ C.G.S. lines of induction. The factor 150 is due to the 150 turns of the exploring coils. The change in distribution as given in scale divisions was then multiplied by 1·398, giving the change in distribution in C.G.S. lines of induction for each $2{\cdot}17^{\text{cm}}$ of length, that being the distance the coils were moved at each step. In determining the difference of distribution the angles observed were quite small; the largest was

less than 2°, making the angular throw of the needle less than one degree. The deflections in scale divisions were therefore taken as proportional to sin $\frac{\theta}{2}$. The error in case of the largest reading would not exceed one part in 3,500; and as the results are obtained by snbtraction of two throws, the error in the result may be neglected.

Specimen Calculation.

Magnet A.—Middle to North End.

Steps.	Average observed throw at 14° C.	Average observed throw at 99·°5 C.	Corrected throw at 99·°C.	Difference in distribution in scale divisions.	Difference in distribution in C.G.S. lines of inductions.
I	18·0	17·5	18·3	— 0·3	— 0·4
II	18·4	18·1	18·9	— 0·5	— 0·7
III	11·8	12·6	13·2	— 1·4	— 2·0
IV	— 7·2	— 4·2	— 4·4	— 2·8	— 3·9
V	—34·3	—27·2	—28·4	— 5·9	— 8·3
VI	—42·0	—27·7	—28·9	—13·1	—18·3
VII	—49·0	—19·4	—20·3	—28·7	—40·2
End	— 5·4	— 2·2	— 2·3	— 3·1	— 4·3

In getting the sum of the distributions it was found necessary to make use of the formula on p. 187, because the angles were too large to take sin $\frac{\theta}{2}$ proportional to tan 2θ. The corrected readings were reduced to absolute measure in the way just described. Thus we have the sum and difference of the linear distribution of the two magnets in absolute measure. One half the sum plus one half the difference gives the distribution of one magnet; and one half the sum minus one half the difference gives that of the other. The distribution at the higher temperature was obtained by subtracting the change in distribution due to the heating from the distribution at the lower temperature. The induction at each point of the magnet was obtained by adding up the number of lines of induction passing out of the magnet beyond that point.

Tables of the results for magnets A and B are given on pages 192 and 193. The first column gives the distance of the exploring coils from the centers of the magnets at the end of each step. The second and fourth columns give the number of C.G.S. lines of induction passing out from the magnet at 14° C. and 99°·5 C. respectively in the step of the coil shown in the first column. The third column gives the change in distribution. The fifth and sixth columns give the magnetizations at the two temperatures, i. e., the number of C.G.S. lines of induction per square centimeter of cross-section passing through the mag-

net at the point indicated. In these columns two values are given for the middle point of the magnet, calculated from the two ends, and serve to indicate the degree of accuracy attained. The second and third columns, from which all the others are calculated, give the means of at least five or six separate determinations which agree well among themselves. The results were further checked by slipping the coils from the middle of the magnets clear off each end at both temperatures. The variation between this measurement and the others was always less than one half of one per cent. This was considered quite

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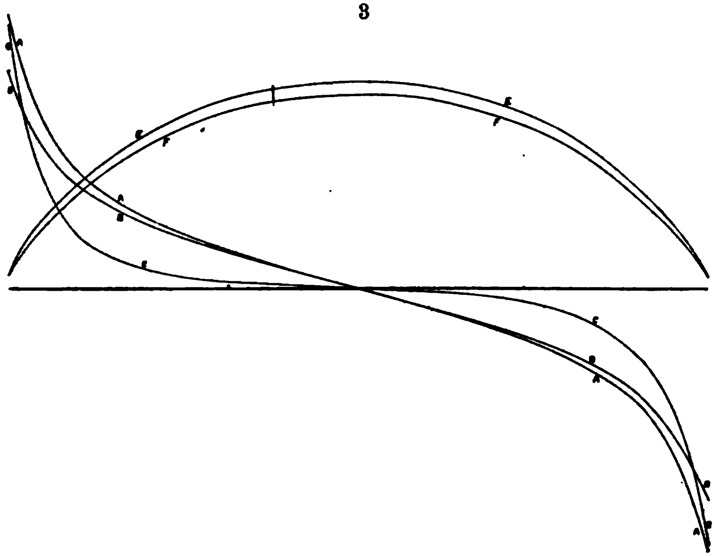

good, as it was impossible to slip the coils over this whole distance as quickly as they were slipped over the small divisions. In figures 3 curves for magnet A are given as follows: AA is the distribution curve at 14° C. BB is the distribution curve at 99°·5 C. CC is a curve showing the change in distribution due to change in the temperature (14°−99°·5 C.). The scale of ordinates is ten times that in AA and BB. EE is a curve giving the induction in the magnet at 14° C. FF is a curve giving the induction in the magnet at 99°·5 C.

The tables on pages 192 and 193 together with the curves for distribution give us sufficient data to calculate the magnetic moments of the magnets A and B at both temperatures. In the tables we are given n, the number of lines of induction issuing from little divisions of the bar throughout its length, as well as the distance d of these divisions from the center of the magnet. A first approximation to the moment is given by the formula

$$M = \frac{1}{4\pi} \sum nd.$$

To this value the following correction was added: If AB in figure 4 is the length of one of these divisions of the magnet, and CD a part of the distribution curve supposed to be straight, then the area ABDC represents the number of lines of induction issuing from the magnet in the length AB. Let F be the center of gravity of the triangle CED. It is evident that the portion of the distribution represented by the triangle should be multiplied by the abscissa of F, not of H, therefore a correction $\sum$ area CED$\times$GH was added to the summation already given. From this calculation the following results were obtained:

	Magnets.	A.	B.
M_{14}	Moment at 14° C.	2298	2060
$M_{99\cdot5}$	Moment at 99·°5 C.	2140	2018
$M_{14}-M_{99\cdot5}$	Loss.	158	142
$\frac{M_{14}-M_{99\cdot5}}{M_{14}}$	Proportional loss.	0·0687	0·0689
	Intensity at 14° C.	322	289
	Intensity at 99·°5 C.	300	283

The magnetic moments were also determined by the method used in the first part of this investigation with the following results:

	Magnets.	A.	B.
M_{14}	Moment at 14° C.	2359	2091
$M_{99\cdot5}$	Moment at 99°·5 C.	2197	1947
$M_{14}-M_{99\cdot5}$	Loss.	166	146
$\frac{M_{14}-M_{99\cdot5}}{M_{14}}$	Proportional loss.	0·0686	0·0687
	Intensity at 14° C.	339	298
	Intensity at 99°·5 C.	316	277

The difference between these two sets of values is considerable, amounting to two per cent in the case of magnet A. This may be due to the fact that only an approximation could be made to the moments of inertia of the magnets because of the holes in the ends, where a slight error would affect the result materially, as the distance from the center was above 15^{cm}. The moments of inertia were calculated by dividing the magnet into two parts, an inner core and an outer shell extending beyond the core at both ends. On the other hand, it is to be noticed that the ratios $\frac{M_{14}\ M_{99\cdot5}}{M_{14}}$ differ by less than one part in 300. In this ratio the moment of inertia of the magnet is eliminated.

In his paper on magnetic distribution, Prof. Rowland gives the following formula for the linear distribution in a magnet

$$\lambda=\frac{\mathfrak{H}\,(e^{rx}-e^{-rx})}{4\pi\sqrt{\mathrm{RR}'}(e^{rb}+e^{-rb})},$$

in which R is the resistance of unit length of the rod, R′ is the resistance of the medium along unit length of the rod, $2b$ is the length of the magnet, x is the distance from the center of the magnet, and $r=\sqrt{\dfrac{\mathrm{R}}{\mathrm{R}'}}$.

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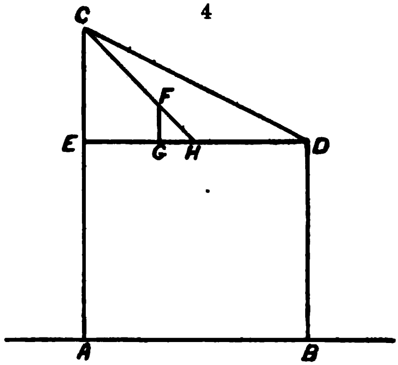


At 14° C. the formula for magnet A may be written

$$4\pi\lambda=167\,\frac{e^{0\cdot125x}-e^{-0\cdot125x}}{e^{0\cdot125b}+e^{-0\cdot125b}};$$

at 99°·5 C.,

$$4\pi\lambda=161\,\frac{e^{0\cdot1242x}-e^{-0\cdot1242x}}{e^{0\cdot1242b}+e^{-0\cdot1242b}}.$$

III. *Discussion of Results.*

The first series of experiments shows that the proportional change in magnetic moment due to change in temperature is greater for short than for long magnets; and that the magnet having the greater intensity of magnetization suffers the less proportional change. This last result is not in agreement with the observations of Wiedemann given on page 180. A little consideration will show, however, that Wiedemann's method cannot be relied upon to give accurate results for the change in magnetic moment. He placed a magnetometer needle before the magnet and observed the deflection of the needle for two temperatures of the magnet. If the center of magnetic attraction had remained at the same point of the magnet during the

temperature changes, his method would have given correct results; but, as will appear from the second part of this investigation, the ends lose a greater proportion of their magnetism than does the middle, and therefore the center of magnetic

Magnet A.

Distance from center of magnet.	Distribution at 14° C.	Change in distribution.	Distribution at 99°·5.	I_{14} Induction at 14° C.	$I_{99·5}$ Induction at 99°·5.	$\frac{I_{14}-I_{99·5}}{I_{14}}$
	70·1	− 4·3	65·8			
15·20				296·	278·	·060
	428·5	−40·2	388·3			
13·03				2106·	1918·	·089
	285·4	−18·3	267·1			
10·86				3309·	3044·	·080
	204·9	− 8·3	196·6			
8·68				4175·	3875·	·071
	146·8	− 3·9	142·9			
6·51				4795·	4479·	·065
	91·2	− 2·0	89·2			
4·34				5180·	4586·	·062
	56·6	− 0·7	55·9			
2·17				5419·	5092·	·060
	18·6	− 0·4	18·2			
0				{ 5498· / 5453· }	{ 5169 / 5126 }	·060
	−17·9	0·	− 17·9			
2·17				5377·	5050·	·060
	−55·5	+ 0·4	− 55·1			
4·34				5143·	4818·	·063
	−96·9	+ 2·5	− 94·4			
6·51				4734·	4420·	·066
	−142·1	+ 3·2	−138·9			
8·68				4134·	3834·	·072
	−199·9	+ 6·2	−193·7			
10·86				3289·	3015·	·083
	−276·3	+14·8	−261·5			
13·03				2122·	1910·	·100
	−432·6	+39·2	−393·4			
15·20				294·	247·	·159
	− 69·7	+11·2	− 58·5			

attraction travels towards the middle of the magnet as the temperature rises. Since the attraction varies inversely with the square of the distance, and since the quantities to be determined are obtained by subtracting the observed quantities, it is evident that the change in magnetic distribution renders Prof. Wiedemann's method inaccurate. This error does not enter in the present investigation, in which the magnetic moments were

determined by swinging the magnets in the earth's field. The results obtained are summed up in the table on page 184.

The second series of experiments shows that the proportional change in distribution of magnetism due to change of tempera-

Magnet B.

Distance from center of magnet.	Distribution at 14°	Change in distribution.	Distribution at 99°·5.	I_{14} Induction at 14°.	$I_{99 \cdot 5}$ Induction at 99°·5.	$\frac{I_{14}-I_{99 \cdot 5}}{I_{14}}$
	61·0	− 3·9	+ 57·1			
15·20				258·	242·	·062
	359·5	−39·6	+319·9			
13·03				1777·	1594·	·103
	227·6	−15·1	+212·5			
10·86				2738·	2491·	·090
	159·7	− 6·0	+153·7			
8·68				3413·	3141·	·079
	139·4	− 3·4	+136·0			
6·51				4002·	3716·	·071
	108·1	− 2·1	+106·0			
4·34				4458·	4163·	·066
	81·4	− 1·5	+ 80·0			
2·17				4802·	4501·	·062
	43·5	− 0·1	+ 43·4			
0				{ 4986· 4950·	{ 4685· 4650·	·060
	3·6	+ 0·7	+ 4·3			
2·17				4965·	4668·	·060
	− 36·2	+ 1·1	− 35·1			
4·34				4812·	4520·	·060
	− 79·8	+ 2·0	− 77·8			
6·51				4475·	4191·	·063
	−128·3	+ 2·4	−125·9			
8·68				3933·	3659·	·069
	−188·6	+ 6·6	−182·0			
10·86				3136·	2890·	·078
	−266·3	+19·0	−247·3			
13·03				2011·	1845·	·082
	−406·4	+35·4	−371·0			
15·20				294·	277·	·057
	− 69·7	+ 4·1	− 65·6			

ture is greatest at the ends and least in the middle of the magnet. A glance at the tables given above, or at the curves in fig. 3, will show this. This is different from the result obtained by Poloni, who found the proportional change sensibly constant throughout the magnet. It could not be expected that the small difference noticed here could be detected by his method, which consisted in measuring two large quantities and

subtracting them in order to obtain a small difference. In the method employed in this research the quantities measured differed but little in size from the quantities desired, and much greater accuracy was easily obtained.

The following is suggested as the explanation; Prof. Ewing has recently made an important addition to Weber's theory of magnetism, in claiming that the forces which hold the little molecular magnets in position are largely the mutual attractions and repulsions of these molecular magnets among themselves. In applying Ewing's theory to the case in hand let us consider a row of magnetic molecules ABC, etc.

A B C   H I J K L

J is held in position by the action of H,I, etc. on the one side and K,L, etc. on the other side, while A has only B,C, etc. to act upon it. It is evident that the force holding J in position is greater than that acting on A. Suppose the bar of which this line of molecules is a part is heated. If in this process the energy of vibration of A and J receive equal increments, it is evident that the increase in the amplitude of vibration of A will be greater than that of J. The magnetic moment contributed by each molecule is the moment of the molecule resolved along the direction of magnetization of the bar. The moment contributed by A would therefore suffer a larger proportional loss on heating than that contributed by J, and so the loss would be greatest at the ends. This explanation will also account for the fact that the proportional change in magnetic moment is greater in short magnets, because in short magnets the end regions of these lines of molecular magnets will naturally form a larger part of the whole line than in long magnets. We should also expect these lines of molecular magnets to be longer when the intensity of magnetization was greater. This would account for the fact that the change in magnetic moment due to temperature changes is less the greater the intensity of magnetization. This appears from the curve given in fig. 1. There are other facts which point in the same direction: When a magnet is heated before it has reached the permanent state, Kupfer found, as already stated, that the proportional permanent loss was greatest at the ends. In some rough tests I have made on this point, heating the bar almost to redness, I have found the permanent proportional loss at the ends nearly twice as great as at points near the center of the magnet. This would naturally follow from Ewing's theory, for the force holding the end magnetic molecules in position being less, they would be more easily set into such violent vibration as to swing out of one position of equilibrium into another.

Western Springs, Ill.

ART. XVIII.—*On the Chemical Composition of Axinite;* by W. E. FORD.

Introduction.—Axinite has long been one of the important silicates whose chemical composition has been in doubt. A number of analyses have been made of material from different sources and of widely differing character, but without revealing any substantial agreement in the ratios between the various oxides. Two formulas are generally given by Dana, Hintze, and other authorities, which disagree with each other to a marked extent; one as derived by Rammelsberg, $HR_3BAl_2(SiO_4)_4$; the other by Whitfield, $H_2R_4(BO)Al_2(SiO_4)_5$. Still a third formula, $HR_4(Al,B)_2(Al.SiO_5H)(SiO_4)_3$, is given by Groth in his *Tabellarische Übersicht der Mineralien.* In view of the uncertainty regarding the composition of this important mineral the present investigation was undertaken with the hope that a few carefully executed analyses would furnish the data needed for determining the chemical formula.

Material for Analysis. — Axinite crystals of beautiful quality from the classical locality of Bourg d'Oisans in Dauphiné were used in making Analysis No. I. The material was broken up coarsely and the crystalline fragments picked over carefully by hand, only clear and transparent pieces which were entirely free from any associated mineral being used. Analysis No. II was made on material from Obira, Province of Bungo, Japan, which was selected with the same care as described above. This is a new occurrence of axinite, of a yellowish brown color with a resinous luster, the material being transparent to translucent. The crystals will be described in a note at the end of this article. Axinite from Franklin, N. J., analyzed by Genth* and studied crystallographically by Penfield* has also been examined; well authenticated specimens of this material having been preserved in the Brush collection. In this case, however, it was only found necessary to supplement the work of Genth by making new determinations of water.

Method of Analysis.—In general the method of analysis need only be briefly described. Silica was determined as usual, with the precautions suggested by Hillebrand.† The sesquioxides were separated from manganese and other bases by a basic acetate precipitation, and manganese was weighed as the protosesquioxide after precipitation by bromine vapor. Calcium and magnesium were determined as usual. Fer-

* This Journal (3), xli, 394, 1891.
† Jour. Amer. Chem. Soc., xxiv, 362, 1902.

rous iron was determined by the method described by Pratt.* Water was estimated directly by a method devised by Prof. Penfield which will be described by him in a future number of this Journal. Boron was estimated by the Gooch method† with the modifications suggested by Penfield and Sperry,‡ and by Penfield and Foote.§ It was found necessary to add a little quartz to the first sodium carbonate fusion and to repeat the fusion of the residues at least twice in order to completely extract the boron. The large amount of calcium in the mineral seems to hold the boron quite tenaciously and only by observing the above precautions was it possible to extract all the boron and obtain correct determinations. A careful test was made for alkalies with but a negative result.

Results of Analyses.

Analysis No. I.—Axinite from Bourg d'Oisans. Specific gravity = 3·287.

	I.	II.	III.	Average.	Ratio.		
SiO_2	42·73	42·86	42·76	42·78	·713		÷ ·089 = 8·00
B_2O_3	5·84	6·40	....	6·12	·087		= 0·97
Al_2O_3	18·02	17·67	17·32	17·67	·171	·177	= 1·99
Fe_2O_3	·94	·90	1·15	·99	·006		
FeO	5·94	6·01	6·12	6·02	·083	·622	= 6·99
MnO	3·08	2·90	....	2·99	·042		
CaO	20·13	20·19	....	20·16	·360		
MgO	2·51	2·32	....	2·41	·060		
H_2O	1·37	1·44	....	1·40	·077		
				100·54			

Analysis No. II.—Axinite from Obira, Japan. Specific gravity = 3·028.

		Ratio.		
SiO_2	41·80	·696		÷ ·087 = 8·00
B_2O_3	5·61	·080		= 0·92
Al_2O_3	17·15	·166	·173	= 1·99
Fe_2O_3	1·11	·007		
FeO	2·84	·039	·609	= 7·00
MnO	10·71	·150		
CaO	19·51	·348		
MgO	·21	·005		
H_2O	1·22	·067		
	100·16			

* This Journal (3), xlviii, 149, 1894.
† Amer. Chem. Jour., ix, 23.
‡ This Journal (3), xxxiv, 220, 1887.
§ Ibid. (4), vii, 97, 1889.

Discussion of the Analyses.—In considering the results of the analyses it is first necessary to determine the rôles played by the boric oxide and the water in the mineral. The boric oxide in each analysis gives a simple and constant ratio with the SiO_2 and other oxides, that of SiO_2 to B_2O_3 being 8 : 1, and there seems to be no doubt but that it is always present in definite proportion and not as an isomorphous constituent replacing Al_2O_3. Concerning the water, the percentages in the two analyses are small, and the ratios of $SiO_2 : H_2O$ are 8 : 0·86 and 8 : 0·77, respectively, in both cases falling short of 8 : 1. Moreover, the ratios of SiO_2 to the protoxide bases, less the water, are not constant, being in the two analyses 8 : 6·12 and 8 : 6·23 respectively. If, however, the water is regarded as basic and isomorphous with the other protoxide bases, there are obtained such clear and exact ratios in both cases as to leave no doubt that this is the correct method of interpreting the results; moreover, the high temperature necessary to drive off the water and the study of other analyses, which will be quoted later, only serve to strengthen and reinforce this conclusion. Consequently in obtaining the ratios from the analyses and in deducing the formula of the mineral from them, the water has been considered as basic and as isomorphous with the protoxide group. According to this interpretation the two analyses give very satisfactory results, the ratios yielding almost exactly whole numbers. The ratios are as follows:

	SiO_2	B_2O_3	R_2O_3	RO
I	8·00	0·97	1·99	6·99
II	8·00	0·92	1·99	7·00

These ratios give the formula, which may be expressed as an orthosilicate, $R''_7 R'''_4 B_2(SiO_4)_8$; R'' being chiefly Ca, with varying amounts of Mn, Fe, and Mg, and H_2 in small proportions. R''' is chiefly Al, but replaced always by a little Fe.

Discussion of Former Analyses.—The two analyses by Genth of the beautiful yellow axinite from Franklin seem to have only one defect, namely, that the water is given as loss on ignition; hence the percentage of MnO being high, it would be expected that the partial oxidation of this constituent would cause the results of the water determinations to be low. On studying his analyses they were found to give ratios closely agreeing with those demanded by the new formula with the exception of the protoxides, which were lower than required. It was decided, therefore, to make direct determinations of H_2O on the material in the Brush collection, the results being, as was expected, considerably higher than those given by Genth. The corrected analyses are given below and the ratios, as may be seen, are fully in accord with those given on page

196. Here, again, water is not present in sufficient quantity to give a ratio of $SiO_2 : H_2O = 8 : 1$, but when added to the protoxide bases the ratio of $SiO_2 : RO$ becomes nearly 8 : 7.

Analyses of axinite from Franklin, N. J., by Genth,* with corrected H_2O.

I. Crystalline Axinite.

			Ratio.			
SiO_2	42·77		·712		÷ ·089	= 8·00
B_2O_3	5·10		·073			= 0·82
Al_2O_3	16·73		·162	·168		= 1·88
Fe_2O_3	1·03		·006			
CuO	0·12		·001	·615		= 6·91
ZnO	1·48		·018			
MnO	13·69		·193			
MgO	0·23		·005			
CaO	18·25		·326			
H_2O	1·29	(corrected)	·072			
	100·69					

Water as given by Genth, 0·76.

II. Lamellar Axinite.

			Ratio.			
SiO_2	42·47		·707		÷ ·088	= 8·00
B_2O_3	5·05		·072			= 0·82
Al_2O_3	16·85		·163	·170		= 1·93
Fe_2O_3	1·16		·007			
PbO	0·09		....	·605		= 6·87
CuO	0·11		·001			
ZnO	1·53		·019			
MnO	13·14		·185			
MgO	0·26		·006			
CaO	18·35		·327			
H_2O	1·21	(corrected)	·067			
	100·22					

Water as given by Genth, 0·40.

Analysis of axinite from Bourg d'Oisans by Rammelsberg.†—From the analysis given beyond Rammelsberg derived the formula $HR^{II}_3R^{III}_3B(SiO_4)_4$ which differs but slightly from that obtained from the new analyses; thus by combining the hydrogen in Rammelsberg's formula with the bivalent bases and multiplying by two the formulas become identical. Rammelsberg's formula is the simpler of the two, but it cannot be accepted, as the new analyses never show sufficient hydrogen to satisfy it. Moreover in Rammelsberg's analysis the ratio of $SiO_2 : H_2O$ is 8 : 0·88, not quite 8 : 1, yet so nearly so that he

* Loc. cit. † Zs. G. Ges., xxi, 689, 1869.

was well justified in deriving his formula from the analysis. As shown below, by combining the hydrogen with the bases, the analysis also conforms very well with the new formula, the ratio being 8:0·88:1·97:6·83, or approximately 8:1:2:7.

Analysis of axinite from Bourg d'Oisans by Rammelsberg.

		Ratio.			
SiO_2	43·46	·724		÷ ·090	= 8·00
B_2O_3	5·61	·080			= 0·88
Al_2O_3	16·33	·161	·178		= 1·97
Fe_2O_3	2·80	·017			
FeO	6·78	·094			
MnO	2·62	·037			
CaO	20·19	·360	·615		= 6·83
MgO	1·73	·043			
K_2O	0·11	·001			
H_2O	1·45	·080			
	101·08				

*The analyses of Whitfield.**—Analyses were made by Whitfield, on material from Cornwall and Bourg d'Oisans. From the second of these analyses the formula, $BR^{III}{}_2R^{II}{}_4H_2(SiO_4)_5O$ was derived, which is quoted in a somewhat different form by Dana and Hintze. These analyses have been recalculated and the resulting ratios are given first according to Whitfield's formula and second according to the new interpretation. While the results are unsatisfactory in either case, they will be found to agree more closely with the new formula than with that proposed by Whitfield.

I. Axinite from Cornwall, by Whitfield.

		Ratio.			According to Whitfield.		According to new formula.	
SiO_2	42·10	·701	÷	·070 =	10·00 or	10·00	÷ ·087 = 8·00 or	8·00
B_2O_3	4·64	·066		=	0·94	1·00	= ·75	1·00
Al_2O_3	17·40	·169	·188	=	2·68	3·00	= 2·16	2·00
Fe_2O_3	3·06	·019						
FeO	5·84	·081						
MnO	4·63	·065						
CaO	20·53	·366	·528	=	7·54	8·00	= 7·21	7·00
MgO	·66	·016						
H_2O	1·80	·100		=	1·43	2·00		
	100·66							

* This Journal (3), xxxiv, 286, 1887.

II. Axinite from Bourg d'Oisans, by Whitfield.

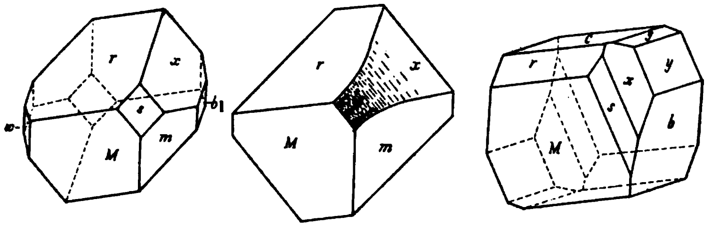
		Ratio.			According to Whitfield.		According to new formula.	
SiO_2	41·53	·692	÷	·069 =	10·00 or	10·00	÷ ·086 = 8·00 or	8·00
B_2O_3 ...	4·62	·066		=	·95	1·00	= ·76	1·00
Al_2O_3 ..	17·90	·173	·197	=	2·85	3·00	= 2·29	2·00
Fe_2O_3 ..	3·90	·024						
FeO ...	4·02	·056						
MnO ...	3·79	·053						
CaO ...	21·66	·386	·513	=	7·43	8·00	= 7·36	7·00
MgO ...	·74	·018						
H_2O	2·16	·120			1·74	2·00		
	100·32							

Without question Whitfield's determinations of B_2O_3 are too low, and they would naturally be so if precautions were not taken to extract all of that constituent by repeated fusions with sodium carbonate and addition of silica.

Conclusion.—As the result of the foregoing investigation it would seem well established that axinite is a silicate in which the boron and the bivalent and trivalent bases are present in definite proportions. Expressed as an orthosilicate the formula is $R^{II}_7R^{III}_4B_2(SiO_4)_8$. The bases are chiefly calcium and aluminum, the Ca being always replaced in part by varying amounts of Mn, Fe, Mg and H_2, while a little Fe is isomorphous with the Al. A little hydrogen seems to be an unfailing constituent of axinite, and expressed as H_2O, the amount is remarkably constant in the analyses. As far as observed however, water is never present in sufficient quantity to satisfy the formula of Rammelsberg, and it seems best to regard it as basic, a rôle which it often plays.

Note on the crystals of axinite from Obira, Japan.—Two distinct types of crystals of axinite come from this locality. The first to be described is that of the material used in making Analysis No. II of this article. These crystals do not occur in separate individuals but in groups, made up of numerous crystals in nearly parallel position, rounding into one another. It is only at the edges of the groups that distinct crystal faces are seen. Measurements were made of these faces, and while as a rule the reflections obtained were poor, the following common forms were readily identified, developed about as represented by fig. 1: *b* (010), *m* (110), *M* (1$\bar{1}$0), *w* (1$\bar{3}$0), *s* (201), *x* (111) and *r* (1$\bar{1}$1). In reality the crystals are so grouped that only the faces shown in the upper right hand portion of the figure are to be seen. A characteristic feature of the crystals is a tendency for the *x* and *s* faces to round into one another, fig. 2 being an attempt to represent this. Still another tendency

is for the crystals to be grouped in nearly but not quite parallel position, all of the crystals curving in one direction corresponding to that of the zone $s - x$. The sharp edge between the x face and the M behind is usually prominently developed and forms the characteristic termination of the projecting crystals.



1 2 3

An entirely different type of crystal was observed on another specimen from the same locality and which is represented by fig. 3. Here in addition to the forms b, M, s, x and r already mentioned, the forms c (001), g (023) and y (021) were observed, and the large development of the zone c, g, y, b gives an unusual habit quite unlike that of ordinary axinite. All of the faces that were identified are represented in the figure.

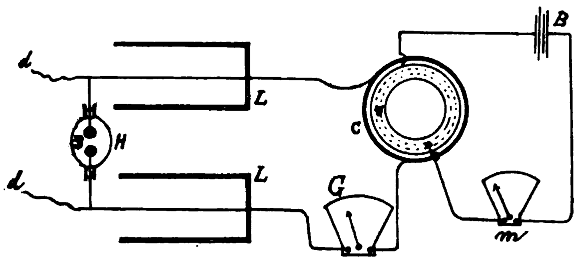
It is with pleasure that acknowledgment is here made by the writer for the constant advice and assistance given him by Prof. S. L. Penfield, during the preparation of this article.

Sheffield Laboratory of Mineralogy,
Yale University, New Haven.

ART. XIX. — *The Electrical Conductivity and Absorption of Energy in the Electrodeless Discharge;* by BERGEN DAVIS, Ph.D.

THE current produced in gases by the electrodeless discharge is very intense but of short duration. This current produces, or is accompanied by, great ionization of the gas subject to the discharge. The object of these experiments was to measure the conductivity produced in gases by the discharge at various pressures. Great care was taken to keep the force producing the discharge uniform throughout the series of experiments. The method of doing this will be readily understood from the arrangement of apparatus, which was as follows:

1



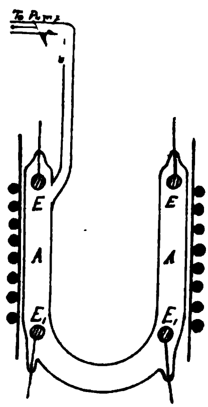
L L (fig. 1) are four large Leyden jars connected two in series and two in parallel. The inner coatings were connected to the spark gap S, and also by the leads *dd* to the terminals of the secondary of a large induction coil, which was driven by an alternating current of 40 periods per second. The outer coatings were connected to the terminals of the coil C surrounding the vessel V. A *hot wire* galvanometer, G, was placed in the discharging circuit for the purpose of regulating and comparing the amount of current passing through the coil C under various conditions. As the potential at which the spark passes and the period are constant, equal currents will represent equal potential gradients around the vessel. Upon the passage of the sparks at S, a strong discharge was produced in the vessel V. The conductivity produced in the gases by this discharge was measured by the galvanometer M, reading to 10^{-6} amperes, connected as shown in the figure.

The vessel V is shown in detailed section in fig. 2. The part of the vessel through which the discharge passed was the annular space AA, between two cylindrical vessels of different diameters placed one within the other, the edges being united at

the top. This space was 8^{mm} wide and 7^{cm} long. The outside diameter of the vessel was $6{\cdot}5^{cm}$. The electrodes were rings of aluminium, extending around at the top and bottom of the annular space. They are shown in section at EE and $E_{,}$ $E_{,}$.

The surface of each electrode was $7{\cdot}38^{sq\ cm}$ and the distance between them 6^{cm}. A constant difference of potential of 220 volts was maintained at these electrodes by the source B. At this potential no current passed between the electrodes except when the discharge was passing. This arrangement of the electrodes made the field of the E.M.F. of the electrodes perpendicular to that produced by the oscillations in the coil C. The component of ionic velocity under the first E.M.F. was independent

2



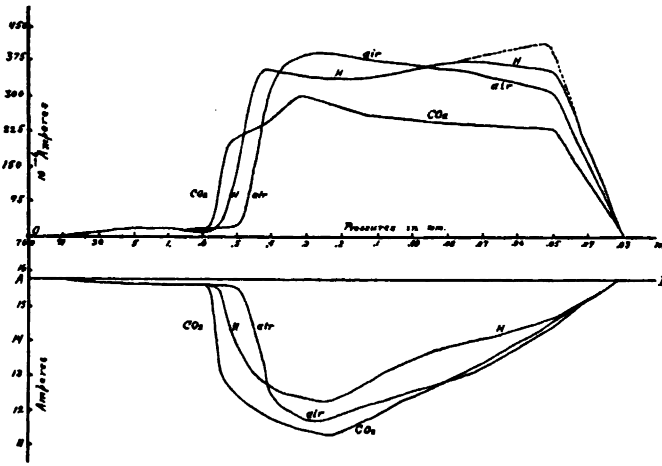
of that produced by the coil. It was found necessary to enclose the spark gap in an atmosphere of hydrogen in order to obtain a uniform discharging potential. The period of the alternating current driving the induction coil was 40 cycles per second, thus giving 80 sparks per second at the spark gap. This rapid succession of discharges gave uniform average readings on the two galvanomters G and M.

If the vessel V were removed from the coil C, on the passage of the sparks, the galvanometer G indicated a large current, being in these experiments 15·8 amperes.

The discharge was allowed to continue until the conditions became steady, and the galvanometer showed a steady deflection. When the vessel, properly exhausted, was put in the coil, the white electrodeless discharge appeared, and the *current* indicated by the galvanometer became very much less. In some cases the reading *dropped back* from 15·8 amperes to about 11 amperes. The amount of drop-back was depend-

ent on the degree of exhaustion and the nature of the gas in the vessel. The amount of heat developed was very great, showing that the gas within the vessel was absorbing a great deal of energy from the system. The *drop-back* of the galvanometer appears to be due directly to the absorption of energy by the gas. Prof. J. J. Thomson* has shown this effect by other methods: That if two coils be placed in series, the presence of a discharging vessel in one coil cuts down the current sufficiently to stop the discharge in the other; also that the discharge in an annular vessel prevents the effect

3



in another vessel placed within the annular one. This screening effect has recently been more fully investigated by E. Lecher.† The conductivity, as measured by the current passing between the electrodes E and $E_{,}$, was found also to vary with the degree of exhaustion and the nature of the gas. The readings were taken as follows: The vessel was either removed from the coil or contained the gas at atmospheric pressure. The alternating current was turned on the induction coil and the sparks allowed to pass until a steady state was indicated by the galvanometer G. Then the vessel was placed in the coil and exhausted. The pressures were measured by a McLoud gauge. The two galvanometers and the pressure were read at the same time.

The curves obtained are shown in figure 3. The curves above the line represent the conductivities of air, hydrogen and carbon dioxide. The abscissæ are decreasing pressures and the

* Recent Researches.

† Deutsche Phys. Ges., No. 18, 1902.

ordinates are conductivities in 10^{-8} amperes. The curves below the line AB represent the readings of the *hot wire* galvanometer. The ordinates taken *downward* represent the decrease of current in the coil caused by the discharge in the vessel. The conductivities, it will be observed, are quite small at large pressures. They rise suddenly to almost a maximum at the appearance of the white discharge.

In the case of air and carbon dioxide the conductivity decreases slightly with decreasing pressure until the pressure becomes $\cdot 05^{mm}$, when the discharge suddenly ceases and the conductivity becomes zero. The conductivity in a gas may be expressed by

$$I = eN(V_p + V_n).$$

As the conductivity remains nearly constant, the number of ions must *decrease* with decrease of pressure, since the mean free path and also the ionic velocity increase rapidly with decreasing pressures.

The conductivity produced in carbon dioxide is considerably less than that produced in air. That for hydrogen is less for higher pressures and greater for lower pressures, than for air. The last reading for hydrogen at $\cdot 05^{mm}$ was not accurate as the discharge began to fail and so gave too small a value. The dotted curve is probably more nearly correct.

The curves below the line AB are dependent on the energy absorbed by the gas. It was quite noticeable that the vessel became hotter at the pressures at which the white discharge first appeared, than at lower pressures. The ordinates of the curves taken downward may be shown to be proportional to the energy absorbed by the gas, as follows: The Leyden jars with the discharging circuit and gas form a free discharging system, in which the current passing through the galvanometer G and the coil may be represented by

$$C = Ae^{-qt} \cos pt.$$

The coil C having a small resistance, the energy is dissipated in the gas and produces damping of the oscillations. The damping is proportional to the energy absorbed, for the galvanometer reads in amperes, while the energy is proportional to the square of the current, consequently:

$$\text{Readings} \propto \int_0^\infty e^{-2qt} \cos^2 pt\,dt$$

$$\propto \frac{2p^2 + 3q^2}{4q(p^2+q^2)}$$

$$\propto \frac{1}{q}, \text{ when either } p \text{ or } q \text{ is large com-}$$

pared to the other.

The readings of the galvanometer are inversely as the damping or as the energy absorbed. It will be observed that the absorption varies with the density of the gas subject to the discharge; also that the absorption in all gases decreases with decrease of pressure.

It was found that if the vessel V were replaced by a single turn of wire whose ends were connected to a non-inductive ohmic resistance, then a definite resistance could be obtained that would produce the same drop-back of the galvanometer as the discharge in the gas. This gives a direct method of measuring the equivalent ohmic resistance of various gases at different pressures without the presence of electrodes.

It was my intention to determine these equivalent resistances, but an accident to the apparatus compelled me to abandon the experiments for that time.

As an illustration of the great absorption of energy and heating of the gas, I will mention the following experiment. A vessel was constructed having a thin platinum wire passing downward through the center. The passage of the electrodeless discharge heated the wire to incandescence in a few seconds.

These experiments were performed at the laboratory of Prof. E. Riecke in Göttingen, to whom I wish to make acknowledgments for the courtesies of the Physical Institute.

Cambridge, England.

ART. XX.—*Geological Structure of New Mexican Bolson Plains;* * by CHARLES R. KEYES.

AMONG the most novel physical features which strike the eye of the traveler as he crosses New Mexico are the broad plains out of which the mountain ridges rise abruptly as volcanic islands out of the sea. These plains are twenty to thirty miles wide, often a hundred miles or more long, and at first glance appear nearly level. Closer aqnaintance shows that they are basins, inclined towards the center and without marked drainage ways or drainage outlets.

With their usual keen appreciative distinctions of geographic features, the Spanish aptly call these inclosed plains "bolsons," meaning a purse. Of these plains, the writer who has brought their Spanish name into geographical usage says:

"These plains, or 'basins,' as they are sometimes called, are largely structural in origin. Bolsons are generally floored with loose, unconsolidated sediments derived from the higher peripheral region. Along the margins of these plains are talus hills and fans of bowlders, and other wash-deposits brought down by mountain freshets. The sediments of some of the bolsons may be of lacustral origin.

"It is essential, in both the geographic and the geologic discussion, to bear in mind the distinction between bolson plains and plateau plains. The plateau plains and the mountains are genetically related, the strata composing the one being bent onto or flexing out into the other. The bolson plains, on the other hand, are newer and later topographic features, consisting of structural valleys between mountains or plateau plains, which have been partially filled with debris derived from the adjacent eminences. The plateau plains are usually destructional stratum plains. The bolson plains are constructional detritus plains filling old structural troughs."†

A distinction between the plateau plains and the bolson plains is as important as it is real. But the statement that bolson plains are constructional detritus plains in structural valleys does not convey a correct idea of the phenomenon, and, as generally understood, the exact signification of the term structural as applied to the character of these valleys is very apt to be misinterpreted. In a carefully qualified sense the valleys occupied by the bolson plains might perhaps be considered structural valleys, but their history is very much more complex and very different from what might be suspected from casual observation.

* Read before the New Mexico Academy of Sciences, December 22, 1902.
† R. T. Hill: Topographic Atlas of United States, Folio 3, p. 8, 1900.

As the type of the bolsons, the Jornado del Muerto may be taken—that vast plain in southern New Mexico which from the time of the early Spanish explorers of the region up to 20 years ago was truly, as its name signifies, a "journey of death." This bolson is more than a hundred miles long and thirty miles wide. On the west are the Sierra de los Caballos and the Sierra Fra Cristobol, rising 3000 feet above the plain. On the east are the lofty Sierra San Andreas and Sierra Oscura. The railroad traverses the middle of the plain from north to south.

The mountain ranges are monoclinal blocks made up chiefly of Carboniferous limestones 1500 feet in thickness and resting directly on quartzites, granites and gneisses. The limestones of the eastern ranges slope westward; those of the western ranges dip eastward. To all appearances, the valley is a simple synclinal trough, the surface of which is covered by gravels. This is the impression that one gets from the train when passing through the region.

Closer examination of the rocks clearly shows that the beds do not lie in a simple syncline of which the mountain ridges are the upward protruding limbs. The strata lie at much higher angles than the general dips of a simple synclinal trough would require. Moreover, near the mountains, especially on the west side of the plain, is a belt three to four miles wide where the surface, so level when viewed from a distance, is found to be trenched by intricately ramifying canyons, often several hundred feet deep. The geological formations are here everywhere well exposed. While the general slope of the plain towards the center is only 2 to 3 degrees, the dips of the strata are often as high as 30 degrees in the same direction, and in places they are even vertical. On the beveled edges of the steeply inclined beds the plain-gravels are laid down; and also broad sheets of basaltic lava, the latter spreading out from numerous low cones.

The geological formations represented are essentially as follows:

Plains gravels (Pleistocene and Tertiary) 5 to 100 feet.
Yellow sandstones (Cretaceous) 4000 feet.
Red Beds (Upper Carboniferous) 1000 feet.
Blue limestone (Middle Carboniferous) 1500 feet.
Gray quartzite 50 feet.
Crystalline complex (exposed) 1000 feet.

A somewhat generalized geological cross-section of the Jornado del Muerto bolson is given below:

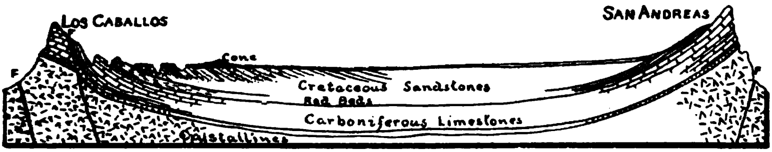


FIGURE 1. Generalized Cross-Section of the Jornado del Muerto.

The sequence of events in the region appears to be briefly as follows: In late Tertiary times, probably, the orogenic blocks began their tilting. Some crushing also took place and sharp local foldings were in evidence. During a pause in the uprisings, at or soon after the close of the Tertiary, the country was beveled off to the condition of a peneplain. Near the main crests of the primitive Los Caballos and San Andreas sierras, where the displacements were greatest, the Cretaceous and Red Beds were largely removed. With a new period of elevation lava flows spread out from various centers of activity, on the upturned beveled edges of the indurated beds. At the Caballo cone, a low volcanic hill on the top of the plains, a section shows the relationships of the various beds as given below:

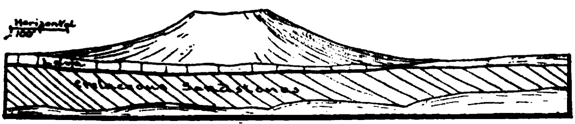


FIGURE 2. Caballo Cone, resting on Cretaceous sandstones.

Very recently a new cycle of stream cutting has been inaugurated. The Rio Grande, which flows southward on the west side of the Los Caballos range, has deepened into a valley 600 to 800 feet below the Jornado del Muerto. The side streams are rapidly cutting back into the great bolson. This period of erosion commenced since the volcanoes were active, for some of their flows are cut in two, and deep canyons mark the paths of the water-courses.

The gravels covering the Jornado are chiefly composed of crystalline pebbles—many of them apparently foreign to the region. The depths of the gravels covering the bolsons appear to have been greatly overestimated. One would naturally expect under the circumstances great thicknesses of detrital matter. The surprise has been the extreme thinness of the detrital materials covering these plains. In the Jornado del Muerto, the underlying Cretaceous rocks are exposed in many places, protruding through the few feet of gravels. Along the

main line of the Atchison, Topeka and Santa Fe railway the shallow cuts frequently expose the indurated bed-rock.

In the La Jara valley, 25 miles south of Santa Fe, where for many miles the plain is covered by gravels, where no indurated rocks are exposed, and where the beveled surface of the Cretaceous was thought to lie many feet beneath the present surface of the plain, drill-holes showed the gravels to be in places scarcely a dozen feet in thickness.

In the broad plain between the Ortiz and Sandia Mountains, east of Albuquerque, similar conditions prevail. At the Una del Gato, the relations of the gravels and the underlying rocks were found as represented in the accompanying cut:

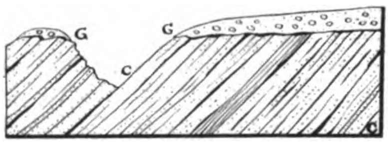


Figure 3. Beveled edges of Cretaceous sandstones, on which Bolson gravels rest, Una del Gato, New Mexico.

If any of these gravels attain the thickness ascribed by Shumard and others (500 feet), these measurements have nowhere been found even approximated to in the bolsons which have come under personal observation.

It must be concluded that the bolsons, or at least some of the principal ones, are not simple structural valleys, in the sense that that term is usually applied, though casual observation so indicates them. Neither is the detritus covering the bolsons so enormously thick as has been claimed.

State School of Mines, Socorro, New Mexico.

ART. XXI.—*Notes on the Marine Turtle Archelon. I. On the Structure of the Carapace, II. Associated Fossils;* by G. R. WIELAND.

IN my first contribution on the osteology of the huge turtle *Archelon ischyros* from the Fort Pierre Cretaceous of South Dakota, I figured (Plate VI, Reference 6*) the last cervical and first dorsal centra, together with the neurals and nine pairs of ribs, as found articulated in their approximately natural position, and associated with most of the other skeletal parts. Since then I have secured much additional material from which it will be possible to mount a quite complete skeleton. But as this will require an amount of time and museum resources equal, for instance, to that involved in the study or mounting of any Dinosaur yet placed on exhibition, a considerable period must elapse before any final contribution on this subject may be made. Hence it may be of some immediate service if the outline of the rib series in its entirety be given now, more especially since this is found to be of unusual interest.

Last autumn I secured near the Cheyenne River in South Dakota, among other material, an important additional skeleton of *Archelon*, in which the first rib, that articulating with the anterior end of the first dorsal centrum, is present. This makes it possible to complete the rib series, as shown in the accompanying text-figure.

In the absence of much careful work by a preparateur it would be difficult to indicate correctly the marginals in dotted line, because of the digitate or strongly serrate character of both the inner marginal borders, which vary much in different portions of the series. The illustration of the completed Carapace must for the present, therefore, remain in abeyance.

Description.—The *nuchal* is a large and handsome T-shaped element one meter in lateral width. I at one time provisionally regarded this bone as belonging to the plastron (7). This view was, however, in the opinion of Capellini supported by "neither embryological nor paleontological evidence" (2); Case in a manuscript note kindly submitted to me likewise opposed it. I am glad to find the complete evidence in accord with the views of these eminent authorities.

The *neuralia* are not of less area than in the Cheloninæ, but they are very thin, and are joined to each other and to the pleuralia by strongly marked, more or less imperfectly interlocking, sutural digitations. They are distinctly grooved on their median

* For convenience the references are grouped at the end of the article.

dorsal line, especially the first seven, this grooving being deepest and widest in the middle of each plate, from whence characteristic surface striations radiate. Regarding the number of neuralia I can only say that the boundaries of the first eight are distinct, but to make out clearly the relations and proportions in the pygal

1

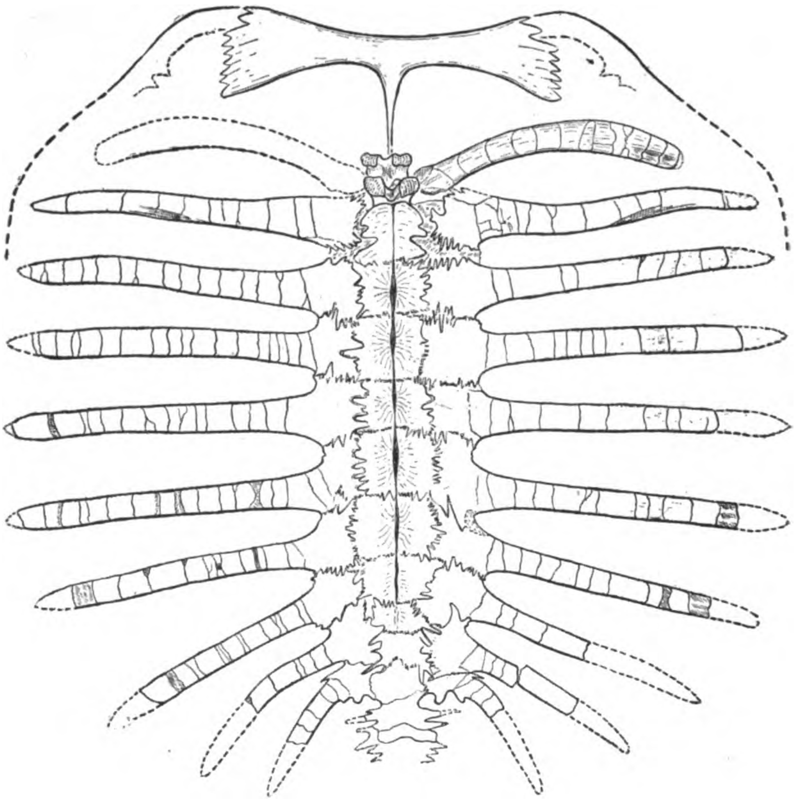


FIGURE 1.—*Archelon ischyros* Wieland. The nuchal, the anterior marginal border of the carapace, the neuralia, the pleuralia, and the complete rib series, with the last cervical and the first dorsal centra.—Dorsal view with nuchal set somewhat forward. (All the dorsal and sacral vertebræ are present and articulated in their natural position in the type specimen, on which the present figure is based, with the sole exception of the first rib.)
One-twentieth natural size.

region cannot now be readily done, in the absence of work by a preparateur. The final median plate shown in the figure is possibly represented as too long. Fortunately, however, the fine specimens I have secured promise when fully elaborated to

supply these and other important details in the osteology of these great turtles. Their discussion may, therefore, profitably await the complete restoration of the types which I later intend to give.

The *pleuralia* are greatly reduced in size, being of even less area than the neuralia, and fully as thin. They unite with each other and with the neuralia by loosely interlocking digitations. The pleural of the second rib in particular is thin and small, occupying only about an eighth of the entire rib length. (See figure.)

The *ribs* are very characteristic, the first being remarkable. The only specimen of this rib recovered is massive, and 74^{cm} in length, or fully three-fourths the length of the second rib, which is one meter long (see measurements). In the Cheloninæ (9) the length of the first rib, which is slender and reduced, is only about one-fourth that of the second. The first rib in *Archelon* is thus much more rib-like in general appearance than in all other turtles with which it may be directly compared, and must have extended out far enough for its distal end to rest in the marginal groove, as in the case of the ends of the other ribs. It is also quite possible that this rib was set even more obliquely to the vertebral column than is shown in the drawing. This point can later be determined. There is, however, no contact between this first rib and the first pleural, *Archelon* differing in this respect from all other turtles except *Dermochelys*.

The *second rib* is also more massive than in any of the Cheloninæ, this being in full accord with the reduced small and thin first pleural which it bears. In the case of the remaining pairs of ribs, which are free for about four-fifths of their length, the only character that need be mentioned now is the distal increase in vertical thickness. The second to the fifth pairs of ribs, inclusive, which are only about $2{\cdot}5^{cm}$ in thickness where they emerge from beneath the pleurals, have near their distal ends a thickness of from four to five centimeters.*

Discussion.—In *Archelon*, as has been noted, the neuralia are strongly reduced in thickness, and the pleuralia in both thickness and area. In fact neuro-pleural reduction is greater than in the case of any other turtle known to possess all the

*In the figure the ribs are drawn in the nearly flattened position in which they were found, the first being the only one preserving the original curvature as in life. The width of the carapace hence appears accentuated. Nevertheless the general form of body was very robust. Indeed there appears to have been an almost Trionychian rotundity, with the nuchal lying more or less athwart the ends of the first pair of ribs (not the second as in the Trionychia), and projecting over from three to four of the cervicals as in *Dermochelys* and certain Pleurodirans, as *Pelomedusa*.

elements of the normal testudinate carapace. On the other hand, the ribs are more fully developed than those of any other fairly well-known turtle, not even excepting *Protosphargis* (1, 2) and *Dermochelys.* In the latter genus, however, the carapace being replaced, in as far as an outer bony shield is concerned, by a strong osteodermal mosaic, there is no necessity for a fully normal development of all the ribs, and such is not present, the anterior pair of ribs being in fact quite as much reduced as in the living Cheloninæ (9). In the latter the first rib, after affording support to the distal extremity of the scapula, flattens and ends against the inner surface of the very large first pleural. And this first pleural, which is in the simpler sense only an expansion of the second rib, is in turn strongly united by suture to the nuchal, the whole arrangement being one of compactness and great strength.

In the absence of a strongly joined nuchal and first pair of pleurals, efficient support for the scapular region of the shoulder girdle would be clearly obtained in one of two ways: Either there must be an increased size of the first rib, or additional strength must be secured by dermal thickening, with or without the development of osteodermal plates. And it is evident that if one of these conditions is found present it may be justly concluded that the other is absent, or but slightly developed. Hence, because of the great strength of the first rib in *Archelon* we may conclude that there was no unusual development of the outer covering of the carapace, whether leathery or of horn, and that there certainly was no osteodermal mosaic as in *Dermochelys.* The entire arrangement of the ribs, and of the supporting bones of the shoulder girdle region in *Archelon* thus forms an exceedingly clear example of *compensatory change.* There is also involved a return to early and primitive conditions. The Protosteginæ (9) as we know were distinctly pelagic, and, accepting the views of Baur and of Dollo, they are, in common with all the marine turtles, descended from ancestors with a normally developed carapace and plastron; while in the case of these ancestral forms we may be quite positive that the neuralia and pleuralia were of strong, and the ribs proper of minor development. Moreover, such forms must, of course, have been descended in turn from Theromeran (3) ancestors in which there was a fully normal rib development. In *Archelon*, therefore, the ribs may be considered as having regained a large and full size quite equal to that which must have characterized the early Theromeran ancestry of the Testudinates, although changed fundamentally in position with reference to the shoulder girdle. The neuralia and pleuralia, on the other hand, have undergone much reduction as compared with the marine turtles of to-day, the margi-

nalia remaining strong to robust. With reference to the first pair of ribs a word remains to be said. It would seem positively certain that in the ancestry of the Protosteginæ these ribs were much suppressed, but for the fact that in *Proganochelys*, as described by Fraas (5), the first pair of ribs has a wholly unique development. In this, the most ancient turtle known, the first rib is very large, and of peculiar form, the distal end being widely expanded, but in the vertical direction. In *Archelon*, however, the very slight distal expansion is lateral, and there does not appear to be much in common with this terrestrial Pleurodiran from the Keuper that would suggest even remote ancestral relationship.

The return to a primitive condition, as seen in the ribs above noted, has seldom been demonstrated. The only other well-authenticated instance of such return among the vertebrates within my ken is that of the canines of the camels as explained by Dr. J. L. Wortman. In the Eocene camels, the canines are small and incisiform; in the Oligocene and Miocene forms, these teeth assume an enlarged and normally caniniform pattern, while in the Pliocene and modern forms they again take on the primitive Eocene condition.

Although it does not as yet seem possible to me to correlate the carapacial changes just described directly with those most probably undergone by *Dermochelys*, it is believed that the example of compensatory skeletal change here recorded must be regarded as a highly interesting one.

Measurements of *Archelon ischyros.*

(*a*) *The First Rib.*

(From specimen about 12/13 the size of the type.)

	M.
Greatest length	·74
Circumference, 18·5^{cm} out from head	·225
Width half-way from head	·075
Width 50^{cm} from head	·09
Girth " "	·23
Depth of head in the dorso-ventral direction	·15
Least circumference about 30^{cm} from head	·21

(*b*) The length of the second, third, fourth, fifth, and sixth ribs, respectively, in the type specimen, is ·95, 1·01, 1·02, 1·02, and 1·01 meters. (The first rib would be 80^{cm} long.)

(*c*) The width of the first to tenth ribs of the type taken at their middle point is, respectively, (·08), ·075, ·075, ·078, ·075, ·07, ·065, ·06, ·055, and ·05 meters.

II.—*Associated fossils.*—With *Archelon ischyros* and *Marshii* there occurs in the uppermost 100 feet of the Fort Pierre (No. 4 Upper Cretaceous), as developed on the Cheyenne River, a series

of immediately associated forms of more than ordinary interest. In the first place, I have obtained in this same horizon well preserved toe bones of a Dinosaurian nearly of the form and nearly as large as those of *Claosaurus annectens*, which I shall figure later as *Claosaurus* (?) *affinis* sp. nov. And presumably from the same drift from a not far distant shore, I secured an exquisitely preserved new species of Palm stem, later to be described as *Palmoxylon cheyennense.*

Secondly, associated with these land forms are numerous Mosasaurs, a shark (a broad-toothed *Lamna*), a fish allied to *Beryx*, a Saurocephalodont, and the following invertebrates,—*Nautilus De Kayi* (very abundant in the matrix of one of the large turtle skeletons), *Placenticeras placenta*, *Scaphites nodosus*, *Emperoceras Beecheri* Hyatt, *Baculites ovatus* and *compressus* Say, *Callista Deweyi* M. and H., *Inoceramus*, etc., etc.—I hope again to call attention to this interesting assemblage, for it is not often that we are able to find in unquestioned association such well marked land and marine forms.

Yale University Museum, New Haven, Conn.

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ART. XXII.—*The Ionization of Water and of Phosphorus Nuclei.* (*Supplementary paper*); by C. BARUS.

1. IN the preceding paper,* I gave a revision of my views of the motion of the nucleus, showing that they admitted of an extension sufficient to include the exceptional and unexpected behavior of the water nucleus in the electric field, within the limits of potential used in my experiments.

I have since pursued the question into further detail and completed the computation for water nuclei and for phosphorus, so far as the data now admit. In equation (3) § 14 of the paper cited, I will put $K = k + UE/(r_2 - r_1)$, and proceed to find

$$1-\epsilon^{-a} = 1-\epsilon^{-\cdot 377Kl(r_2+r_1)/V}$$

for a series of values of K, as follows:

$K=$	$1-\epsilon^{-a}=$	$K=$	$1-\epsilon^{-a}=$
·001	·013	·2	·925
·01	·121	·4	·994
·05	·476	·8	1·000
·1	·736	1·0	1·000

This curve may be constructed in a chart in which K is the abscissa and $1-\epsilon^{-a}$ the ordinate. In the exponent, $2r_2 = 2{\cdot}10^{\text{cm}}$, $2r_1 = {\cdot}64^{\text{cm}}$, $l = 50^{\text{cm}}$, $V = 2$ lit/min. Meantime, one may note that if K and l vary reciprocally, the result remains unchanged. An inspection of the curve shows that the marked flexure occurs at about $K = {\cdot}2$.

Now if the results for water nuclei (l. c., chart fig. 4) be compared with this curve, the two cases are seen to be quite similar and the marked flexure of the former occurs at about $E = 10$ volts as the electromotive force of the condenser. Since for water nuclei the specific velocity in the non-electric field is negligible, $k = 0$ and $K = UE/(r_2 - r_1)$. Hence if for coördination the points of marked flexure be regarded identical, $K = {\cdot}2$, corresponds to $E = 10$ volts, roughly, and thus

$$U = \frac{\cdot 2 \times \cdot 73}{10} = \cdot 0146 \text{ cm./sec.}$$

2. If the velocity U of the nucleus be computed from the estimated radius R and the viscosity of the air, as in § 5, the data are, since $RU = {\cdot}125 \times 10^{-6}$ in a field of volt/cm.

* This Journal (4), vol. xv, pp. 105–120, 1903. Cf. § 14. The notation is the same in both papers: E denoting the potential, C the effective capacity of the condenser; n the number of nuclei per cub. cm., e the charge of each, k their absorption velocity, U their combined ionic velocity; r refers to the radii, l to the length of the condenser and t is the current time.

$$R = 10^{-6\text{cm}} \qquad U = \cdot 125 \text{ cm/sec}$$
$$R = 10^{-5\text{cm}} \qquad U = \cdot 012 \text{ cm/sec}$$

if $l = 50^{\text{cm}}$.

Since $R = 10^{-5\text{cm}}$ is the superior limit of size* found from subsidence considerations, it appears that U is probably larger than ·012 cm./sec., if $l = 50^{\text{cm}}$, and hence this value of U computed purely from viscosity is in agreement with the value of U just deduced from purely electrical data.

Furthermore, the order of size and the velocity deduced are compatible with my work on the structure of the nucleus, $k = \cdot 001$ to $\cdot 03$ being here the specific velocities in the absence of the electric field. Hence k is small compared with $UE/(r_2 - r_1)$, the condition supposed.

3. The behavior of the phosphorus emanation is next to be treated. Here the value of k, or the specific velocity of the nucleus in a given cardinal direction, was found by direct experiments to be $k = \cdot 3$ cm./sec. Hence the value of the exponential factor, $1 - \epsilon^{-a}$, even when $E = 0$, is about ·96 and may therefore be neglected as experiment showed. Consequently in this case

$$-(dE/dt)/\dot{E} = \frac{16 \cdot 7\, n_0 e V}{C(r_2 - r_1)} \frac{U}{k}$$

as heretofore stated, where, moreover, for want of direct knowledge, $U = k$ was assumed. This is virtually supposing, since here $RU = \cdot 125 \times 10^{-6}$, that the size of the phosphorus nucleus is $R = \cdot 42 \times 10^{-6\text{cm}}$, a datum which, provisionally at least, is admissible.

If the nuclei are larger than this, the factor U/k must be evaluated in computing n_0 from $2 \cdot 3\, a = (dE/dt)/E$, as

$$n_0 = (k/U)(2 \cdot 3\, a C(r_2 - r_1))/16 \cdot 7\, eV.$$

Now it is suggestive to observe that the datum for n_0 for tubular condensers was always *low* as compared with the same datum for plate and for spherical condensers.

Thus	from plate condensers,	$n_0 = 33 \times 10^4$
	from spherical condensers,	$n_0 = 39 \times 10^4$
	from tube condensers,	$n_0 = 8 \times 10^4$

I attributed this with some misgiving wholly to want of saturation in the latter case since an influx tube is inevitable.

But in the value of n_0 for plate and spherical condensers the value of k does not enter, and the results depend simply on U. Hence what was supposed to be wholly undersaturation was probably, in part, the neglect of the factor k/U. Put, there-

* There would be coincidence for $R = 8 \cdot 6 \times 10^{-6}$.

fore, $n_0 = 2{\cdot}3aC(r_2 - r_1)/16{\cdot}7\,e\,V$ as the approximate equation for the nucleation at the influx pipe of the tubular condenser, while

$$n_0' = n_0 k / U$$

is equal to the datum found for plate and spherical condensers. Hence if $k = {\cdot}3$ cm./sec. for the phosphorus emanation, a lower limit of U, is

$$U = kn_0/n_0' = {\cdot}3 \times 8/36 = {\cdot}067 \text{ cm./sec.}$$

In other words, the velocity of the phosphorus nuclei in the unit (volt/cm.) field is about ·07 cm./sec. The radius of the phosphorus nucleus will then be

$$R = {\cdot}125 \times 10^{-6}/{\cdot}067 = 1{\cdot}9 \times 10^{-6} \text{ cm.},$$

i. e., about 4·5 times larger than the value obtained under the assumption of $U = k$.

4. The results thus found for phosphorus nuclei make it necessary to reopen the computation of n for plate and spherical condensers. The assumption formerly made was $U = k$, as a normal case and in the absence of available guidance. It is well, therefore, to summarize the equations used as follows:

For plates, $-(dE/dt)/E = A\,Un_0 e/Cx\epsilon^{ax/A}$, where A is the area, x the distance apart, a the linear edge of the plates. Herefrom, if $U = 1$ cm./sec. $n_0 = 33 \times 10^4$.

For tubes, $-(dE/dt)/E = 16{\cdot}7\,V\,Uen_0(1 - \epsilon^{-a})/(r_2 - r_1)kC$, whence if $U = k$, $n_0 = 8 \times 10^4$.

For spheres, $-(dE/dt)/E = 4\pi e\,Un_1/CR$, where R is the radius, n_1 the nucleation for radius 1^{cm}. Herefrom, $n_1 = 39 \times 10^4$, if $U = 1$ cm./sec.

The value of U for the phosphorus emanation has been estimated anew in the preceding paragraph as about ·07 cm./sec. Consequently these equations all need corresponding corrections. Since n_0 varies as $1/U$, the estimated diminution of U increases n, $1/{\cdot}07 = 15$ times. Thus the number of nuclei computed for $U = {\cdot}07$ cm./sec., and for complete saturation of the phosphorus emanation will be

from	plates,	$n_0 = 4{\cdot}9 \times 10^6$
	tubes,	$n_0 = 5{\cdot}4 \times 10^6$
	spheres,	$n_1 = 5{\cdot}8 \times 10^6$

results which contain the most careful revision of the subject which I have been able to make. Note that in computing U for phosphorus, l the condenser length does not occur as the exponential term vanishes. The datum $k = {\cdot}3$ cm./sec. was found by direct experiments with the steam tube (Exp. with Ion. Air, Chap. 3). The ratio k/U follows from comparison of tube with plate and spherical condensers. The method here

is then independent of the one used for water nuclei, the latter being not applicable to phosphorus at all. It is obvious, however, that in the light of the experience now gained, a complete repetition of the experiments is desirable, since in tubular condensers there is necessarily undersaturation, the effect of which is to decrease n_0.

Unfortunately the coronas are not as directly available with the phosphorus emanation as with water nuclei; for while the condenser determines the nucleation of the air immediately after it has passed over phosphorus, condensation can only be produced in vessels in which the nucleation is either dilute (small charge of emanation added to a large bulk of air), or is stale, while the initial coronas are mere fogs. Thus the procedure carried out for water nuclei fails for phosphorus, but I shall show in a succeeding paper how it may be supplemented, and that the data of a purely optical method are of the order of those just found from a purely electrical method.

5. The question now arises whether the effect of a field in removing nuclei more or less completely may be explained. If $U = e/6\pi\mu R$, the current will be, per square centimeter,

$$i = \frac{E}{x} \cdot \frac{ne^2}{6\pi\mu R}$$

where E/x is the potential gradient. For the same current in the unit field, $ne^2/\mu R = ne V/\mu =$ constant, or the number of nuclei needed will depend inversely on the square of their charges and directly on their radii; or in a given medium will depend inversely on the energy of their charge.

The question takes rather a different form, inasmuch as it is of interest to know how the number of charges removed by the field compares with the total number present in and added from without to the medium during this interval. The case may be worked out for the cylindrical condenser, as above.

If time losses of nuclei and charges other than are due to absorption at the walls of the vessel be ignored, and if n nuclei are present at the section $l = 0$ and n at the section l of the condenser,

$$n = n_0 \epsilon^{-\frac{2\pi k l(r_2 + r_1)}{16 \cdot 7\, V}}$$

In the absence of the field this equation determines the spontaneous loss of charges whether the nuclei are spontaneously lost or not; but in the presence of a field the charges are more rapidly removed because of the added velocity imparted to the nuclei. Moreover for water nuclei, k may usually be neglected in comparison with $UE/(r_2 - r_1)$. In other words, $K = UE/(r_2 - r_1)$, and

$$n/n_0 = 10^{-\cdot 163Kl(r_2+r_1)/V}$$

is the relative nucleation at the right section l of the tube condenser.

The following table contains results for a number of typical cases. For phosphorus, if perfectly fresh, $k = \cdot 3$ cm./sec., while the velocity of the nucleus in the unit field is $U = \cdot 067$ cm./sec., as a lower limit.

TABLE I.

Number of nuclei (n/n_0) in successive right sections of the tubular condenser, length $l = 50^{cm}$, diameters $2r_2 = 2{\cdot}10^{cm}$, $2r_1 = \cdot 64^{cm}$. $V = 2$ liters/min. E in volts, k in cm./sec.

	Ratio n/n_0, if			Ratio n/n_0 if $U = \cdot 015$ cm./sec., and			
l	$k = \cdot 3$	$k = \cdot 03$	$k = \cdot 003$	$E = 10$	$E = 50$	$E = 100$	$E = 1000$
0	1·00	1·00	1·00	1·00	1·00	1·00	1·000
1	·93	...	...	·95	·76	·59	·005
5	·67	...	...	·77	·26	·07	...
10	·46	·93	·99	·60	·07	...	
20	·21	·86	·98	·36	...		
30	·09	·79	·98	·21			
50	·02	·67	·96	·08			

For the case of water nuclei* if obtained from solutions of concentration

	1 %	·01 %	·0001 %	
$k =$	·0008	·0013	·03	cm./sec.

while $U = \cdot 73/l$ cm./sec., where l the effective condenser length has been taken. The table takes the excessive value $l = 50$.

Consequently the first part of the table shows the relative nucleation in different sections of the condenser when k has the values stated. The first column would apply to fresh phosphorus nuclei, the last two for water nuclei obtained from different dilute solutions in the absence of an electric field. Most of the phosphorus nuclei should vanish, but the water nuclei are but slightly reduced on leaving the condenser. One may note the small velocity of current $V = 2$ liters/sec.

The second part of the table shows the case for water nuclei when the core of the condenser has different potentials, E, for the assumed velocity, $U = \cdot 015$ cm./sec. in the unit electric field, since k may here be neglected. If $l = 5^{cm}$, the column for 10 volts would apply at 100 volts, etc. It is seen that the charges of nuclei are speedily absorbed while, from the evidence given by coronas, the number of nuclei falls off but slightly.

6. It thus becomes a question of crucial importance to ascertain whether the charges are actually lost to a few per cent in

* This Journal (4), xiv, p. 225, 1902.

the first few centimeters of the condenser, or very near the influx tube. A condenser was, therefore, constructed the length of which could be varied by placing earthed tubes, $2r_2=2\cdot10^{cm}$ in diameter and of different lengths, $l=60, 30$, and 15^{cms}, around a fixed charged insulated core, $2r_1=\cdot64^{cm}$, concentrically with the usual precautions.

Table II shows the results in which the insulation of the condenser was determined before and after each measurement with the nucleated medium. The condenser lengths 60 and 15^{cms} are inserted as a sufficient contrast.

TABLE II.

Effect of length of tubular condenser. $dV/dt = 1\cdot9$ liters/min.

		Leakage ds/dt			
Length	Charge at	Before	During nucleation.	After	Current $i\times10^{11}$ amperes.
60^{cm}	+80 volts	·02	·42	·00	1·07
15^{cm}	+80 volts	·05	·45	·00	1·12
15^{cm}	+80 volts	·00	·47	·02	1·20
15^{cm}	−80 volts	·03	·26	·00	·62

It is seen that the current is certainly quite as large, *caet. par.*, when the length of the tube condenser is 15 as when it is 60^{cm}. It is actually larger at 15^{cms} due to the gradual enlargement of the needle holes in the lead jet* whereby fresher nuclei are conveyed into the condenser. The current for positive and for negative charges have the usual relation to each other.

The experiments showed another interesting fact already pointed out elsewhere, that the current, ds/dt, increases as the water level in the receiver rises or as the discharge into the condenser is fresher. One naturally inquires what the maximum charge of each nucleus would be if there were no conveyance tube. In the present installation this jet was unable to charge the condenser, the charging current being less than 10^{-13} amperes, about of the same order as the leakage.

One may conclude, therefore, that the loss of charge per minute, i. e., the current radially traversing the condenser, is practically independent of its length if the latter exceeds a few centimeters, for the air current and width given. All but a few per cent of the charge are lost in the first few centimeters ahead of the influx tube of the condenser. The experiments are thus in keeping with the surmize of Table I.

7. *Summary.*—In case of water nuclei it was found from coincident electrical current graphs, $Ul = \cdot73$, and if the con-

* The fine holes clog with lead hydrate when the jet is left standing in a damp atmosphere, and the obstruction is gradually removed by the friction of the water. Old jets long unused, therefore, show small electrical currents as compared with new jets.

denser length is $l = 50^{cm}$, the combined velocity of the charge in the unit field is $U = \cdot015$ cm./sec.

From considerations relating to the viscosity of the medium it was found that $RU = \cdot125 \times 10^{-6}$ and if U is taken equal to $\cdot015$ cm./sec., as just stated, $R = 8 \times 10^{-6}$ follows for the radius of the water nucleus. A superior limit $R = 10^{-6cm}$ would follow from subsidence considerations.

From direct experiments on the diffusion of nuclei (this Journal, xiv, 225) for solutions of initial concentrations of $\cdot01$ per cent and $\cdot0001$ per cent, $k = \cdot0013$ and $\cdot03$ cm./sec., respectively. These values of k are necessarily much smaller than $UE/(r_2 - r_1)$, and the data are confirmatory.

From measurements of the apertures of coronas, $n = 10^3$ to 10^4 nuclei per cubic centimeter.

In case of phosphorus nuclei, $k = \cdot3$ cm./sec. for the velocity of the nucleus in a given direction, and in the absence of the electric field was found directly from experiments with the steam jet and absorption tube.

In the electrometer work with this emanation, $U = \cdot07$ cm./sec. and $R = 1\cdot9 \times 10^{-6cm}$ follow from a final comparison of the nucleation data n_0' for plate or spherical condensers (full saturation) with the nucleation of tube condensers, n_0 (deficient saturation), since here $U = kn_0/n_0'$. Thus U increases with n_0, and if n_0, by specially devised methods, is increased to $2n_0$ (which has been possible), $U = \cdot14$ cm./sec. and $R = 10^{-6cm}$ follow.

Finally the nucleation for complete saturation was $n_0 = 5 \times 10^6$ nuclei per cubic centimeter; but if U can be raised to $\cdot14$ cm./sec. as just stated, $n_0 = 2 \times 10^6$. The nucleation of the saturated phosphorus emanation thus exceeds a million per cub. cm. at the surface of the phosphorus. It is, therefore, larger than I at first made out, and in a subsequent paper I shall show that the same order of values follows from the purely optical experiments made with coronas.

It is because of this general consistency in the results of experiments so widely different in character, that I venture to adhere to the essentials of my old hypothesis.

Brown University, Providence.

Art. XXIII.—*On a Method of Demonstrating Newton's Colors by Transmitted Light;* by H. N. Davis.

It is well known that if white light be passed through a thin film, part of it will be reflected twice within the film and will cause interference and color phenomena. These are usually very faint because the amount of light that is thus reflected is so small as compared with what passes directly through, as to have but a slight effect. If, however, the same wave-front be passed through a uniform series of films, successive portions of certain colors should be blotted out in each film, while other colors which get through the first film without interference, should emerge from each of the other (similar) films without interference, and the color effect should be cumulative,

At the suggestion of Professor Barus, these surmises have been empirically verified, and excellent results obtained. If a number of wire rings of the same size be mounted in parallel planes, and dipped together into a soap solution, their planes being kept perpendicular to its surface, a suitable series of films results, through which light can be passed and caught on a sheet of paper, showing the desired phenomena very beautifully. Since each film, under the action of gravity, is a very thin wedge, the colors are in horizontal bands, appearing first at the top (where the wedge is thinnest) and moving slowly down across the field as the films evaporate, to be succeeded by other bands of lower orders. Indeed good films will often hold until two-thirds of the field is colored with the yellowish-brown of the first order. And if the paper be replaced by a good lens, and the colors projected on a large scale upon a suitable screen, they can be strikingly demonstrated to a class. Some of the effects obtained in this way are most magnificent, even rivaling the best of our autumn sunsets, until it is only with reluctance that one concedes the essential dissimilarity between the two phenomena. In practice, the important thing seems to be uniformity in size and alignment in the set of rings. I have found it convenient to make them some $5{\cdot}5^{cm}$ in diameter, using galvanized iron wire ($d=1{\cdot}2^{mm}$) and forming each around a pattern of wood or metal, the ends being twisted together into a sort of handle. Such rings can be temporarily strung on three rods, notched at appropriate intervals to insure parallelism in the planes of the rings, while the "handles" are being clamped between two pieces of soft wood. The rings should be at least a centimeter apart to avoid cylindrical and irregular films, and from fifteen to thirty are sufficient. A tin

trough of such dimensions as just to admit the set facilitates the dipping.

During the course of this experiment, before the films have become thin enough to show colors, certain other phenomena of a circulatory character are very noticeable. These may be studied most easily in the projected image of a single film, and for observations on conditions immediately after formation, it is convenient to support a ring on the shorter branch of a J-shaped "handle" and to fix it permanently in the focus of the projecting lens, a narrow trough being raised so as to submerge the ring when necessary. The moving images are of two kinds, one corresponding to pear-shaped air-bubbles running up at the sides of the film, the other to spheroidal drops running down through the middle. These sets of images are always of opposite colors, and if, under given circumstances, the air-bubbles show white and the drops black, then moving the film some 4^{cm} away from the lens will reverse the colors, the bubbles showing dark and the drops white. From this it is evident that the latter act as convex lenses with real foci (bright spots) some 2^{cm} in front of the film, while the bubbles are concave lenses with virtual foci 2^{cm} behind it.

These air-bubbles require but little explanation, but the drops are more interesting. The happenings in a typical film (dipped at a time $t=0$) are as follows: At first its image is clear, but almost immediately a few large drops appear at various parts of the film and begin to descend. These "wanderers" are much larger than their successors ($d=0{\cdot}5$ or $0{\cdot}6^{mm}$) and their number varies from one to a dozen, being largest when a preceding film has dried on the ring and has not been removed. At $t=1$ sec. a "skirmish-line" has formed about a third of the way down, above which line the film is closely dotted with drops. This travels down in the film about as fast as do the color-bands later, reaching the bottom at $t=$about 8 sec. The drops in its front rank are usually small, but a half a centimeter behind come the largest of the "ordinaries" ($d=0{\cdot}2$ to $0{\cdot}3^{mm}$) and after these a succession of smaller ones until (at $t=60$ to 100 sec.) the film begins to show colors and great viscosity is noticeable. The size of the average drop is some $0{\cdot}2^{mm}$ and, roughly speaking, the size of those passing a given point decreases as t increases. The velocity of descent varies from 0 to 7^{mm} per sec. (that of the wave front averaging $5{\cdot}7^{mm}$ per sec.) and is greater (1) for large drops, (2) for drops near the bottom of the ring and (3) at times corresponding to small values of t, but, if other things are equal, is nearly the same at all points in the same horizontal line. A number of observations gave an empiric formula $v^2=2p\,(y-q)$ (y being the distance from the top of the ring, and p and q functions of t, the former decreas-

ing—very rapidly at first—and the latter increasing as t increases). This formula is, of course, a rough approximation, but analogies between it and $v^2=2gs$ are very interesting. These "drops" are not simply bulges due to variations in the surface tension of a film (for similar phenomena appear in the image of a thin glass cell filled with solution) but are little globules floating in the liquid, composed of a more concentrated solution with greater density and refracting power, and with a surface tension with respect not only to air but to the rest of the solution; though the process by which such definitely separated globules are formed is not quite clear.

It is not unlikely that further study of the nature, form, and velocity of such descending masses, both in films and in thin cells (where they are spheres and the surrounding medium is stationary) may lead to a method of investigation not only of changes in viscosity due to evaporation but possibly also of the problems of surface-viscosity, in connection with which further knowledge would be very desirable.

Brown University, Providence, R. I.

Art. XXIV.—*Note on the Amphibole Hudsonite previously called a Pyroxene;* by S. Weidman.

Desiring to make a comparison of the microscopic appearance of the mineral hudsonite with a certain pyroxene occurring in the quartz-syenite of central Wisconsin, the writer requested of and received from Professor S. L. Penfield of Yale University sufficient mineral for this purpose. The material sent the writer is a portion of the specimen* sent from Cornwall, Orange County, New York, to Professor Brush in 1853 by S. R. Horton, and which is the same as that sent by the latter to Professor L. C. Beck† about ten years earlier, from which the original description of the mineral hudsonite in 1842 was made.

Thin sections of hudsonite having been made and placed under the microscope, it was seen by the prismatic cleavage of 56° and 124° and by the optical properties of low birefringence, strong pleochroism and absorption, that this mineral is an amphibole, and not a variety of pyroxene as it has always been supposed. Cleavage fragments of the mineral measured by a hand goniometer also readily showed the prismatic cleavage to be that of amphibole. Since this mineral has been listed as a member of the pyroxene group for nearly sixty years in all works on mineralogy, it was thought a brief statement concerning its history and character would be of interest.

History of Hudsonite.—The name hudsonite was proposed by Dr. Louis C. Beck‡ for a new species of mineral, in 1842. The description by Dr. Beck is as follows: "Color, black, often with brownish tarnish. Streak, green. It occurs massive, exhibiting one very perfect cleavage like some varieties of pyroxene. Luster vitreous to resinous. Opaque. Hardness from 4·5 to 5; specific gravity 3·5. Alone before the blowpipe it fuses with effervescence into a black bead, which is attracted by the magnet. This mineral, which is proposed as a new species, was found by Dr. Horton in a vein of quartz in the town of Cornwall, Orange County. Its composition, according to my analysis, is as follows:

Silica	37·90
Oxide of iron	36·80
Alumina	12·70
Lime	11·40
Magnesia	1·92
	100·72"

* This Journal, xvi, 369, 1853.

† Nat. Hist. of New York, Part III, Mineralogy, p. 405, 1842.

‡ Loc. cit.

Hudsonite was later classed by Dana* with pyroxene, although there is no record of a further examination of it. Dana's classification was accepted by Beck† in 1850.

Brewer‡ in 1850 also made an analysis of this mineral with the following result:

SiO_2	36·94
Al_2O_3	11·22
Fe_2O_3	trace
FeO	36·03
MnO	2·24
CaO	12·71
MgO	----
	99·14

The density of the mineral, according to Brewer, is 3·43 to 3·46.

In 1853 Smith and Brush§ made two new analyses of the hudsonite, the mineral being supplied by S. R. Horton and being the same, as already stated, as that sent by him to Professor L. C. Beck. The analyses of Smith and Brush are as follows:

SiO_2	39·30	38·58
Al_2O_3	9·78	11·05
FeO	30·40	30·57
MnO	·67	·52
CaO	10·39	10·32
MgO	2·98	3·02
K_2O	2·48	4·16
Na_2O	1·66	
Ignition	1·95	1·95
	99·61	100·17

The presence of 1·95 per cent of water (ignition) in the analyses of such careful analysts as Smith and Bush indicates that the mineral analyzed was amphibole rather than pyroxene. The analyses of Smith and Brush are more nearly complete than those of Beck and Brewer, and taking this into consideration, it is seen that the four analyses clearly confirm one another. No other work on the mineral hudsonite, to my knowledge, has been done since that of Smith and Brush in

* System of Mineralogy, 2d ed., 1844.

† Third Ann. Report of the Regents of the University of New York on the condition of the Cabinet of Natural History, p. 131, 1850.

‡ Liebig-Kopps's Jahresberichte, p. 712, 1850.

§ This Journal, xvi, 369, 1853.

1853. This was long before the microscope came into use, and hence nothing was known concerning its optical properties.

Description of the Amphibole Hudsonite.—The macroscopic appearance of the hudsonite closely agrees with the original description by Beck. Its color is black to brownish black. Luster, vitreous. Besides the very perfect prismatic cleavage of 54° to 56°,* there is a well developed transverse parting with distinct twinning lamellæ parallel to the parting, which is identical in character and position with that described by G. H. Williams† in actinolite. This parting or pseudo-cleavage is a marked feature of the hudsonite. On the orthopinacoid it forms striations normal to the prismatic cleavage, and on the clinopinacoid the striations make an angle of about 76° with the prismatic cleavage. These structure planes are common in pyroxene, where they are considered to be in the plane of the basal pinacoid. It was very likely this pronounced parting which led Beck to liken this mineral to pyroxene in his original description.

Under the microscope the mineral is seen to be free from alteration, but it contains a few small areas of limpid quartz and a very slight infiltration of extraneous material in the older fractures. Following Tschermak and Dana, the plane of parting and of twinning lamellæ above noted is considered the basal pinacoid (001) in order to make it correspond with the similar structural plane in pyroxene, instead of considering it in the plane of the orthodome ($\bar{1}01$) in accordance with other text-books. A thin section which was cut as near as possible in the plane of the clinopinacoid showed the transverse parting planes to form an angle of about 76° with the prismatic cleavage, and thus the slide was cut sufficiently near the plane of the clinopinacoid to furnish the extinction angle of the hudsonite. A series of measurements showed the plane of extinction to be about 9° from the vertical axis in the obtuse axial angle β. This axis of elasticity, being apparently less than the one normal to it in this plane, it is considered the $\mathfrak{c}$ axis, and hence $\mathfrak{c} \wedge \dot{c} = +9°$. The optic angle and character could not be satisfactorily determined. The pleochroism is pronounced and absorption strong: $\mathfrak{a} =$ light olive green, $\mathfrak{b} =$ green with slight tinge of yellow, $\mathfrak{c} =$ green with slight tinge of blue. Absorption, $\mathfrak{c} \gtrsim \mathfrak{b} > \mathfrak{a}$.

While transverse parting in actinolite and common green hornblende parallel to the base (001) has been observed‡ by a number of writers, twinning lamellæ parallel to this plane apparently

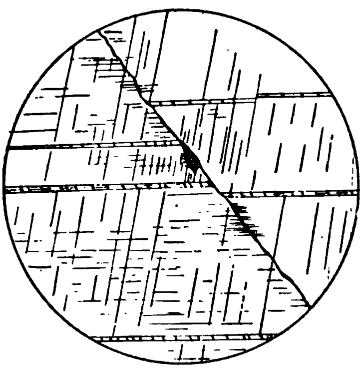
* Prof. Penfield has since measured the angle of the prismatic cleavage with a reflection goniometer and found the values $m \wedge m = 55° 31'$.

† This Journal, xxxix, 352, 1890.

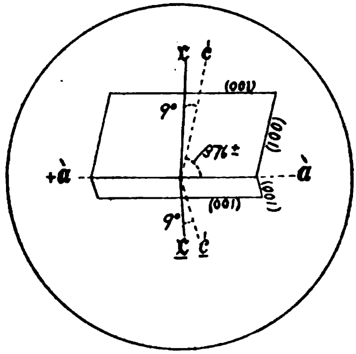
‡ See Zirkel, 2d ed., i, 300.

has not been so commonly noted. In the hudsonite the twinning lamellæ vary considerably in width, having a maximum breadth of 0·02ᵐᵐ in the several sections examined. The larger lamellæ are usually continuous across the section, while the smaller ones often thin out into mere lines or end abruptly at a fracture. The appearance of the twinning lamellæ in a portion of a slide parallel to the clinopinacoid (010) is shown in figure 1. The short and thin lamellæ or parting planes are concentrated along the fractures, and thus bear witness that the twinning and parting, like the fractures, have a secondary dynamic origin. The larger and more continuous lamellæ are probably connected with larger fractures in the mineral not seen in the slide. Figure 2 represents the optical orientation and its relation to the structural planes of prismatic cleavage and basal twinning and parting as seen in the plane of the clinopinacoid.

1



2



The occurrence of transverse twinning lamellæ and parting planes in amphibole, like those described in the hudsonite, corresponding to similar structure planes in pyroxene, where they are considered parallel to the basal pinacoid, is only another instance showing the wisdom of the method of giving the same symbols to these analogous planes in both groups as first suggested by Tschermak in his Lehrbuch der Mineralogie, in 1884, urged by a number of writers, and finally fully adopted by Tschermak and Dana in their text-books. The several cogent reasons for this change were well stated by Mügge* and Williams† a number of years ago and need not be repeated here. Because of this change adopted in the orientation of amphibole so as to correspond throughout with pyroxene, there is necessarily a lack of uniformity in literature in describing the relations of

* Neus. Jahrb. f. Min., 1889, i, 244. † This Journal, xxxix, 356, 1890.

the optical axes to the crystallographic orientation of the amphiboles. According to Dana and Tschermak, for instance, the axis of least elasticity in amphibole, as in pyroxene, lies in the obtuse axial angle β, whereas according to Zirkel, Rosenbusch, Groth, Des Cloizeaux, Hintze and others who consider the basal pinacoid (001) of Tschermak and Dana the orthodome ($\bar{1}01$), the axis of least elasticity lies in the acute axial angle β. For the sake of greater clearness, therefore, it would seem to be advisable, when the axial angle and the axes of elasticity are referred to, for each writer to state which of the two orientations is adopted.

The writer is indebted to Mr. J. L. Nelson, graduate student in geology, assisted by Professor W. W. Daniells, professor of chemistry in the University of Wisconsin, for the following analysis of the hudsonite:

SiO_2	36·86
TiO_2	1·04
Al_2O_3	12·10
Fe_2O_3	7·41
FeO	23·35
MnO	0·77
CaO	10·59
MgO	1·90
Na_2O	3·20
K_2O	1·20
H_2O at 110° C.	0·70
H_2O at red heat	0·60
	99·72

This analysis differs from that made by Smith and Brush in showing the presence of 1·04 per cent of TiO_2 and 7·41 per cent of Fe_2O_3. It is probable that neither of these constituents were sought for by Smith and Brush, the TiO_2 being weighed with the SiO_2, and the whole of the iron being considered as FeO. The few inclusions of quartz in the hudsonite are sufficient to cause an appreciable variation in the determination of the amount of SiO_2. With this explanation the analysis of Smith and Brush may be considered to agree very closely with that made by Nelson and Daniells. From the above analysis and those previously made it will be seen that the hudsonite does not correspond in composition with the common amphiboles, but is closely related to barkevikite, hastingsite, and similar alkali-amphiboles. For the sake of comparison the hudsonite is grouped with some of the amphiboles near it in composition in the following table:

	I	II	III	IV	V	VI	VII	VIII
SiO_2 ...	43·85	42·00	36·86	42·46	38·41	35·42	34·18	36·78
TiO_2 ...			1·04			1·34	1·53	
Al_2O_3 ..	4·45	12·00	12·10	11·45	17·65	8·89	11·52	15·13
Fe_2O_3 ..	3·80		7·41	6·18	3·75	9·73	12·62	14·46
FeO ...	33·43	30·00	23·35	19·93	21·75	24·48	21·98	22·89
MnO...	0·45	0·25	·77	·75	0·15	1·17	0·63	
CaO ...	4·65	11·00	10·59	10·24	10·52	6·93	9·87	5·14
MgO ..	0·81	2·25	1·90	1·11	2·54	0·17	1·35	0·93
Na_2O ..	8·15		3·20	6·08	2·95	5·13	3·29	4·00
K_2O ...	1·06	trace	1·20	1·44	1·95	3·23	2·29	0·42
H_2O ...	0·15	0·75	1·30		·24	3·15	·35	·25
	100·80	98·25	99·61	99·64	99·91	99·64	99·61	100·00

I—Arfvedsonite, Kangerdluarsuk, Greenland. Lorenzen, Min. Mag., v, 50, 1882. II—Noralite, Nora, Westmanland, Sweden. Klaproth, Beitrage, v, 153, 1810. III—Hudsonite, Cornwall, N. Y. Analysis by J. L. Nelson and W. W. Daniells. IV—Barkevikite, Barkevik, Norway. Analysis by G. Flink, Brögger, Zeit. d. Kryst., xvi, 142, 1890. V—Barkevikite, Square Butte, Mont. Lindgren and Melville, this Journal, xlv, 292, 1890. VI—Amphibole, Beverly, Mass. F. E. Wright, Tschermak's Min. u. Petrog. Mitth., xix, 312, 1900. VII—Hastingsite, Dungannon, Ontario. Adams and Harrington, this Journal, ii, 213, 1896. VIII—Bergamaskite, Monte Altino, Bergamo, Italy. Lucchetti, Groth's Zeitschr., vi, 199.

These amphiboles are seen to have a low content of silica, and if the content of TiO_2 had been determined in each case, it is likely the similarity in amount of SiO_2 as well as TiO_2 would be still more apparent. Next in amount to silica is the iron, which prevails in the protoxide form; the alumina is abundant though variable; the lime is greatly in excess of magnesia; and the alkalies, especially soda, occur in considerable quantity. The amphibole noralite was analyzed by Klaproth in 1810 and the analysis should be taken with some reservation, for good methods for determining the mineral constituents, and especially the alkalies, had not at that time been devised. The noralite, however, seems well worthy our attention in comparison with the other amphiboles of this table. The hudsonite appears to be more nearly like VII, hastingsite, in composition than the others. Their optical properties, especially the inclination of the plane of extinction to the vertical axis, appear to be quite variable. So far as recorded, the angles of extinction are as follows: arfvedsonite, $\mathfrak{c} \wedge \dot{c}\,(3) = -14°$; hudsonite, $\mathfrak{c} \wedge \dot{c} = +9°$; barkevikite, Barkevik, $\mathfrak{c} \wedge \dot{c} = +12\frac{1}{2}°$; barkevikite, Square Butte, $\mathfrak{c} \wedge \dot{c} = +13°$; amphibole, Beverly, $\mathfrak{c} \wedge \dot{c} = +21$. So far as principal features of composition are concerned, all these amphiboles might well be placed in the same class with arfvedsonite, though retaining in each case their varietal names on account of slight differences in composition and in optical properties.

Geological and Natural History Survey of Wisconsin,
Madison, Wisconsin.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Crystallized Hydrogen Peroxide.*—It is announced by Wilhelm Städel, that, contrary to previous assertions, hydrogen peroxide crystallizes with ease and in a very distinct manner. Its melting point is about $-2°$. A preparation containing 95 to 96 per cent of hydrogen peroxide remained liquid in a freezing-mixture at $-20°$; but in a mixture of solid carbon dioxide and ether it solidified to a hard mass. It appeared to be necessary to cool the preparation to a temperature between -20 and $-23°$ before it solidified. If a trace of the solid material is thrown into the liquid cooled to -8 or $-10°$, magnificent needle-shaped crystals immediately form, which are as clear and transparent as water, and which soon permeate the whole mass. By draining the mother-liquor from these crystals and allowing them to fuse, then repeating the crystallization, peroxide of hydrogen free from water is obtained.

A number of reactions were tried with the anhydrous substance: an extremely small quantity of platinum-black produces catalytic action accompanied by a violent explosion; powdered manganese dioxide, or a mixture of carbon and metallic magnesium with a trace of manganese dioxide, takes fire immediately when put in contact with the substance; finely-divided metallic iron is without action, but when a little powdered manganese dioxide is added the iron burns and throws off sparks; powdered lead is ignited in the same manner; a few drops of anhydrous hydrogen peroxide, when thrown upon wool or moist sponge, immediately bursts into flame; concentrated sulphuric acid can be mixed with it if this is done at a low temperature, but if the temperature is allowed to rise too high, oxygen very rich in ozone is given off.

It appears that the problem of preparing anhydrous hydrogen peroxide on a large scale has been solved by the process which has been described, while the pure product thus produced shows an unexpected degree of stability. A well-packed sample was carried on an ordinary truck for seven days over a distance of 50 or 60 kilometers without undergoing more than a slight change under these unfavorable circumstances.—*Zeitschr. angew. Chem.*, 1902, 642. H. L. W.

2. *Fumarole Gases from Mount Pelée.*—Moissan has analyzed samples of gas carefully collected by Lacroix from a fumarole of the Blanche River after the catastrophe of May 8th, 1902 and before the eruption of Aug. 30th of the same year. It is reported that pieces of lead placed in the mouth of the fumarole melted rapidly, while zinc remained solid, so that it is assumed that the temperature was about 400°. It is stated that the opening was in conglomerate, and that an abundance of sulphur and ammo-

nium chloride was deposited about it. Four separate samples gave nearly the same results as far as the chief constituents were concerned, and one of the samples more fully examined gave the following results:

Carbon dioxide	15·38
Oxygen	13·67
Nitrogen	54·94
Argon	·71
Carbon monoxide	1·60
Methane	5·46
Hydrogen	8·12

The gas as it was emitted was mixed with much steam. It contained also traces of hydrochloric acid and sulphur vapor, but hydrogen sulphide, acetylene and ethylene were absent and no helium was found. The gas is peculiar when compared with gases described from other volcanic eruptions, in containing a considerable quantity of the combustible gases, hydrogen, carbon monoxide and methane. Moissan calls attention to the poisonous nature of the gas, due to the carbon monoxide in it, and he suggests that many of the victims of the eruption may have died from breathing it. No comment is made in regard to the presence of large amounts of oxygen with combustible gases, but it seems incredible that such a mixture could have existed in the incandescent regions of the volcano, and hence it appears to be certain that the combustible gases, whatever their origin may have been, were mixed with atmospheric air at a comparatively low temperature.—*Comptes Rendus*, cxxxv, 1085. H. L. W.

3. *A New Reaction for Certain Oxidizing Agents.*—L. L. DE KONINCK has found that when one or two drops of nitric acid of sp. gr. 1·35–1·40 are added to a boiling solution of a manganese salt in fuming hydrochloric acid, the color of the liquid changes to a very dark green with a tinge of yellow, owing to the formation of manganese tetrachloride or some similar compound. The color is very stable while the acid is concentrated, but it disappears upon dilution. The test is made with a solution of 0·001^{g} of manganous chloride in 1^{cc}. Besides nitric acid, nitrates, chlorates, hypochlorites, chromates, and lead dioxide give this reaction, while sodium bromate, potassium perchlorate, sodium peroxide, bromine, potassium persulphate, red lead and sodium nitrite do not give it. It is remarkable that sodium bromate and potassium nitrite do not give the reaction, and it is evident that they do not liberate chlorine when treated with hot, concentrated hydrochloric acid. The opposite behavior of lead dioxide and red lead is also very peculiar.—*Chem. Centralbl.*, 1902, ii, 14. H. L. W.

4. *Synthesis of Anhydrous Hydrosulphites.*—By the action of gaseous sulphur dioxide upon the metallic hydrides which have been recently described by him, MOISSAN has prepared the hydrosulphites of potassium, sodium, lithium, calcium, and strontium. The reaction in most cases is very energetic, so that it is neces-

sary to dilute the sulphur dioxide with hydrogen, or to allow it to act at low pressure upon the solid hydrides, in order to avoid decomposition by the heat produced and to obtain pure products. Moissan finds that the hydrosulphites correspond to the formula $M'_2S_2O_4$, and not to $M'_2HS_2O_4$, thereby apparently settling an uncertainty which has existed for a long time. The reaction which takes place in the case of the potassium salt is as follows:

$$2SO_2+2KH=K_2S_2O_4+H_2.$$

The reactions with the other hydrides are analogous to this.—*Bulletin*, xxix, 10. H. L. W.

5. *The Solubility of Boric Acid in Hydrochloric Acid Solutions.*—The statement made in a commonly used hand-book of inorganic chemistry, that boric acid is more soluble in hydrochloric acid than in water, has been found to be incorrect by W. Hertz. His results show that the solubility of boric acid rapidly decreases as the strength of the hydrochloric acid increases until the latter is about four times normal. At this point the solubility is only about one-third as great as in water. As the strength of the hydrochloric acid is then increased up to nine and one-half times normal, the solubility of the boric acid is practically constant. Since the ionic dissociation of boric acid is very slight, it appears that the usual explanation, based upon the decrease of ionization from the effect of the hydrogen ions of the hydrochloric acid, will not apply in this case.—*Zeitschr. anorg. Chem.*, xxxiii, 355. H. L. W.

6. *The Preparation of Pure Iron.*—Iron which was crystalline in structure and pure white in color, which dissolved slowly but completely in dilute sulphuric acid with evolution of odorless hydrogen, has been prepared by Skrabal. A platinum electrode was first coated with iron from a ferrous ammonium oxalate solution, then the electrode thus prepared was used as an anode, and the pure iron was deposited on a platinum cathode in a solution of ferrous sulphate acidified with sulphuric acid. A current of low tension (0·4 volt) was used.—*Berichte*, xxxv, 3404.

H. L. W.

7. *Beitraege zur Chemischen Physiologie;* herausgegeben von Franz Hofmeister. III Band, 1–8 parts. Braunschweig, Vieweg und Sohn, 1902.—The first eight parts of the third volume of Hofmeister's Beitraege bring fresh evidence of the increased attention which is being devoted to the chemical study of the albuminous bodies. It is impossible to review in this place the twenty papers presented; it must suffice to refer in particular to Friedmann's interesting studies of the sulphur-containing groups of the proteids, to the physiological studies on the proteolytic digestion products (Embden and Knoop, Zunz, Langstein), and to Czapek's extensive investigation of proteid synthesis by lower plant organisms. The application of modern physico-chemical methods to the solution of physiological problems is also further indicated in papers by Laquer and Sackur and by Pauli. L. B. M.

8. *Expansion of Melted Quartz.*—The new uses of melted quartz, or more exactly amorphous silica, make the determination of its physical properties of importance. Vessels made from amorphous silica have the remarkable property of acting like metals when subjected to heat. After being heated to a red heat they can be plunged into cold water without injury. L. HOLBORN and F. HENNING have measured the expansion coefficient of this substance and find it to be 0·00000054.—*Ann. der Physik.*, No. 2, 1903. J. T.

9. *Purification of Drinking Water by Ozone.*—The use of ozonized air for this purpose is attracting attention.

The East London Water Company has been carrying out trials at Lea Bridge with one method and appear to be fairly successful. Prof. VAN'T HOFF lately gave some details of the Vosmaer-Lebret process. The ozonizer in this process does not use glass and the silent discharge takes place between the walls of metallic tubes. An electromotive force of 10,000 volts is employed. A large portion of organic matter and of the colonies of bacteria were removed by the process.—*Nature*, Jan. 1, 1903. J. T.

10. *A disturbance-free Torsion Magnetometer.*—The present use of the earth for returns by the electric tramways makes the carefully perfected methods of Gaus and Weber almost useless. F. KOHLRAUSCH and L. HOLBORN describe a new instrument which overcomes many of the difficulties which have arisen in the use of old methods. A complete description of the instrument is given. The position of rest of the suspended portion remains for months with a change of barely one scale division; and the instrument is not affected by the sudden changes due to the electric roads in the neighborhood of the Reichanstalt.—*Ann. der Physik.*, No. 2, 1903. J. T.

11. *Fatal effect of Electric Currents of low Potential.*—It has been often maintained that a potential below a thousand volts is not dangerous to human life. Numerous casualties have shown the fallacy of this belief. The current strength is just as important a factor as the electromotive force. There is no question that a potential of 500 volts with a strength of current such as is employed on the third rail system in our cities is deadly, when good contacts are obtained. A fatal accident occurred at the Fulham public baths in England, on Dec. 28, 1902. Two bathers were killed by standing up in the bath and grasping an electric conductor which ran alongside the baths. The voltage was only 170. Very good contact was obtained.—*Nature*, Jan. 8, 1903.
J. T.

12. *Velocity of X-Rays.*—Mon. M. R. BLONDLOT by an ingenious method has measured this velocity in air and finds it to be the velocity of light. The principle of his method consists in employing the well known property of the X-rays in facilitating the spark discharge. Electric waves along wires were produced and at definite distances it was found that the rays increased the amplitude of these waves. A consideration of wave lengths and

distances of the X-ray bulb gave the data for determination of the velocity of the rays. X-rays of different penetrating power were employed and the velocities of the rays were measured in paraffin, wax, beech wood, vaseline, oil, and essence of turpentine. The velocity was the same in all these media and was equal to the velocity of light in air.—*Comptes Rendus*, Oct. 27, Nov. 3–10, Dec. 29, 1902. J. T.

13. *Sound Waves and Electromagnetics.*—OLIVER HEAVYSIDE calls attention to the photographs of flying bullets taken, some years ago, by Professor Boys, and asks if there is anything analogous in electromagnetics to the mass of air which the photographs showed to be pushed in front of the bullet. Suppose that the electron is jerked away from an atom so strongly that its velocity exceeds that of light. Heavyside discusses the question from a mathematical point of view, and the conclusion apparently is that there are mathematical solutions which give color to the possibility of such a motion of the electron.—*Nature*, Jan. 1, 1903. J. T.

14. *The Physical Papers of Henry Augustus Rowland.* 697 pp., 6 pls. The Johns Hopkins Press, Baltimore.—A committee of the faculty of Johns Hopkins University has edited Professor Rowland's papers as a memorial of their colleague. The bibliography contains 72 titles and of these there are now reproduced: 4 Early Papers (written before 1874); 31 papers on Magnetism and Electricity; 4 papers on Heat; 16 papers on Light; 6 Addresses. A description of the Dividing Engines for ruling gratings is here published for the first time.

15. *Laboratory Manual of Physics;* by HENRY C. CHESTON, PHILIP R. DEAN and CHARLES E. TIMMERMAN. 128 pp. American Book Co.—Three instructors in the New York High School have produced a practical brief manual for elementary work in physics.

II. GEOLOGY AND NATURAL HISTORY.

1. *United States Geological Survey.*—The following publications have recently been received:

BULLETIN No. 196. Topographic Development of the Klamath Mountains; by J. S. DILLER. 66 pp., 13 pls., 7 figs.—The Klamath Mountain region has experienced a long and complicated series of changes beginning with the early Mesozoic. Mr. Diller traces sixteen different movements and erosion stages, beginning with an uplift at the close of the Eocene and ending with the recent Coos Bay subsidence.

BULLETIN No. 197. Origin of Certain Place Names in the United States; by HENRY GANNETT. 280 pp.—The origin of 10,000 names has been investigated and interesting facts regarding local history are brought to light.

BULLETIN No. 198. The Berea Grit Oil Sand in the Cadiz Quadrangle, Ohio; by W. T. GRISWOLD. 42 pp., 1 pl., 1 fig.—A detailed study of the Berea Grit adds proof to the anticlinal

theory of oil and gas accumulation. So direct is this evidence that a map has been constructed for the guidance of prospectors.

BULLETIN No. 199. Geology and Water Resources of the Snake River Plains of Idaho; by I. C. RUSSELL. 185 pp., 25 pls., 6 figs.—Southern Idaho is largely an untrodden field to geologists and Prof. Russell's preliminary report on the region is an important addition to geologic literature. The rocks surrounding the Snake River Plains are pre-Tertiary and consist of granite, rhyolite, quartzite and limestone. The Plain itself is made up of Tertiary and recent lacustral formations and lavas. That volcanic activity was contemporaneous with the existence of the lakes is shown by interbedded basalts, clays, sands and ashes. The Snake River lava is younger than the Columbia lava and the latest outpouring "occurred probably within historical times and are perhaps not over 100 or 150 years old." The lava came from a great number of inconspicuous craters on the plain and in the adjacent mountains and flowed for great distances. One continuous stream is 50 miles long, 1 to 3 miles wide and about 300 feet deep. In the arid climate of Idaho these recent flows have had little opportunity to weather and the details of crater and cone and stream as well as of the bombs and blistered surfaces are unusually well preserved. The illustrations and descriptions in the Bulletin make these facts clear. The drainage of this region exhibits some unusual features, perhaps the most remarkable of which is the abundance of large springs which pour out from the northern wall of Snake canyon between Shoshone Falls and Bliss. They flow steadily throughout the year and in August and September equal in volume the water in the river.

2. *Die Alpen in Eiszeitalter;* by ALBRECHT PENCK and EDUARD BRÜCKNER. Parts 3 and 4, pp. 225–432, with many charts and figures. (Leipzig, Tauchnitz.)—The parts already published of Penck and Brückner's study of the Alps indicate clearly that the completed work will be full and trustworthy. The field observations are abundant and thoroughly justify the inductions based upon them. Pages 225–396 present a continuation of the discussion of the eastern Alpine border (see this Journal xiv, 315), examples of cirques, over deepened valleys, hanging valleys, drumlins inside of moraines, etc. are shown to occur in orderly fashion, and abundant proof is presented for strong erosion by the ice mass. The glacial formations of the Rhine Valley are described and mapped (pp. 396–432).

3. *Lakes of Southeastern Wisconsin;* by N. M. FENNEMAN. 168 pp., 36 pls., 38 figs. Wisconsin Geol. and Nat. Hist. Survey, Bull. viii.—The educational work of the Wisconsin survey is worthy of the highest commendation, and the recently published volume on the physical geography of the lakes of the state will be of material aid to teachers and students. The book is well written and well illustrated. A set of hydrographic maps accompanies the volume.

4. *Publications of the Earthquake Investigation Committee in Foreign Languages*: No. 7, 54 pp., 4 figs; No. 9, 63 pp., 11 figs., 20 pls.; No. 10, 101 pp.; No. 11, 95 pp., 4 pls. Tokyo, 1902.—The great Mino-Owari and other recent destructive earthquakes have given Dr. Omari the data necessary for an exhaustive study of the "Deflection and Vibration of Railway Bridges" (No. 9). Dr. Omari also continues the unfinished work of the late Professor Sekiya, in a paper on "Macro-Seismic Measurements in Tokyo" (Nos. 10 and 11). Professor Tanakadate describes a "Vertical Motion Seismometer" (No. 7), and A. Imamura the "Seismic Triangulation in Tokyo."

5. *Phycologia Boreali-Americana.* Fasc. xix, xx; by F. S. Collins, W. A. Setchell and Isaac Holden.—This valuable work now includes twenty fascicles comprising one thousand numbers besides three fascicles of larger size with 75 numbers. This series of algæ exsiccatæ has never been surpassed in value by any similar work, and, if we consider not only the large number of species issued, the excellence of the specimens themselves and the remote and little explored regions from which in many cases they were obtained, but also the accuracy of the determinations and the detailed synonymy given on the labels, it is doubtful whether the series has ever been equalled. Fasc. xix is devoted to algæ from our Pacific coast as far north as Alaska, which were collected mainly by the botanists connected with the University of California. There is a short preface by Prof. Setchell describing the different regional divisions of the West coast with notes on the collectors of algæ on that coast. Besides such novelties as *Anatheca furcata* and *Fauchea Gardneri* and other characteristic western species, the series of species found also in other regions is important for a comparative study. Fasc. xx includes a new *Pithophora varia* Wittroch, *Rhizoclonium erectum* and *Dichothrix rupicola*, species recently described by Collins, and an interesting set of marine Cladophoræ and other green algæ. The Phycologia is indispensable to all who study the algæ of North America and the authors are to be congratulated on the extent and high quality of their undertaking.

W. G. F.

6. *Fungus Diseases of Stone-Fruit Trees in Australia and their Treatment*; by D. McAlpine. 165 pp., 54 pls. Melbourne, 1902.—Although the study of the plant-diseases of Australia is of comparatively recent date, a number of important contributions to the subject have appeared in the last few years, the latest being that of Prof. McAlpine of the Department of Agriculture of Victoria. The volume, which is very fully illustrated, a number of the plates being colored, brings out the unpleasant fact that, even in a country so remote from Europe and North America as Australia, there is no exemption from the diseases which infest older countries. The leaf-curl of peaches, the prune-rust, the shot-hole disease and numerous others are pests in Australia as well as with us. Nor, unfortunately, is Australia

without its own special fungi which are injurious to fruit trees, for Prof. McAlpine describes more than fifty new species of fungi of different orders which attack fruit trees, and their microscopic characters are well illustrated. The study of plant-diseases in Australia evidently offers a wide field for the mycologist and the pathologist. A chapter is devoted to the treatment of fungus diseases and, if the diseases are numerous, it is also true that, at the present day, much is known definitely in regard to their prevention. Prof. McAlpine's treatise is a valuable contribution to our knowledge of the comparative distribution of injurious fungi. W. G. F.

7. *Das Plankton des Norwegischen Nordmeeres;* by H. H. GRAN, Rept. Norwegian Fishery and Marine Investigations. II, No. 5, 222 pp., 1 pl., large 8°. Bergen, 1902.—This treatise by the well-known algologist, Dr. N. H. Gran, includes both animal and plant-forms of plankton organisms and is divided into two parts, a general and a special. The introduction gives a history of the study of plankton-organisms up to date and is followed by a chapter on the biology and distribution of selected species, of which the accounts of *Halosphæra viridis, Phæocystis Pouchettii* and of a number of pelagic Diatoms and especially of the Peridineæ, are of great interest to botanists. The second part of the volume, after an account of the different stations where collections were made, concludes with a systematic list of the species of both plants and animals included in the work, with notes on their distribution. Among them are several new species belonging to the genera Peridinium and Ceratium. W. G. F.

8. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes.* Edited by J. STANLEY GARDINER. Vol. I, Part III, pp. 223–346, 33 figs., 4 pls.—The material collected by Mr. Gardiner in 1899 and 1900 is gradually being described (this Journal, xiii, 321; xiv, 74). Fifty known species of the Actinogonidiate Echinoderms are listed by Professor F. Jeffreys Bell. Many of them, as the *Ophioœthiops unicolor* Brock (1888), were hitherto known only by a single specimen. Professor Bell again urges the investigation of the question of the reproduction of the disc in certain ophiuroids. "It is clear that, if the gonads of an ophiuroid be set free by the separation of the disc, and if a new disc be formed and new gonads developed, the question of germplasm may be considered settled." In the short list of Orthoptera by Malcolm Burr, one species (*Liphoplus* sp.) is mentioned as possibly new. The third contribution, by L. A. Borradaile, on the Marine Crustaceans of the expedition, is an extended report on the Xanthidæ. Of the 89 species cited, 17 are described as new; for one, a new subgenus (*Platyozius*) is proposed, closely related to *Pseudozius* Dana. Two new genera, *Cæcopilumnus*, type *C. hirsutus* n. sp., and *Maldivia*, type *M. symbiotica* n. sp., are described, whose systematic relationship remains undetermined. Four known species belonging to the Atelecyclidæ and Hapalocarcinidæ are also given. Tate Regan

describes the Fishes taken within the lagoons and from fresh-water pools. Of the latter only one (*Barbus vittatus* Day) is a true fresh-water form. The Marine Turbellaria, by F. F. Laidlaw, contains a systematic list of 15 species, 13 of which are described as new, and many valuable anatomical notes are given with about a dozen text figures and two plates; the general figures being reproduced in colors. Some new and valuable deductions are given in conclusion and under "Natural History Notes" many interesting facts are mentioned, especially in regard to the collecting and preservation of material. K. J. B.

Mr. Gardiner continues his discussion of the formation of coral reefs and adds much that is new (pp. 313–346). He shows that the coral sand rock is formed by twice wetting and drying of the beach sand during the rise and fall of the tide. In the latter process the salts from the sea-water are deposited on the sand grains, many of which are redissolved by being covered by the tide, but carbonate and sulphate of calcium remain and fill the interstices of the sand, binding them together. The sulphate becomes replaced by less soluble carbonates and the rock ultimately formed of nearly pure carbonate of lime, the rock naturally being built from the surface downward. In nearly all cases the slope of the mass is that of the beach and becomes of great density and hardness as it is more and more indurated with carbonate of lime. From the study of such masses off any island the former extent and contour of the land may be deduced with considerable certainty. "The erosion of land in the Maldives, the formation of flats at about the low tide level by washing away of the land and hollowing out of such flats to form first pools, then velu or definite lagoons, may absolutely be traced."

In regard to the formation of lagoons Mr. Gardiner says: "In conclusion, it is a fair deduction that the increase both in depth and extent in the lagoons of the Maldive atolls is mainly due to solution, an important additional factor being the outwash of fine matter by the tidal and oceanic currents. It is obvious, though, that there are two nicely balanced sets of conditions, causing the filling in or increase in size of any lagoon."

The bathymetrical limits of various species of reef-building corals has been determined. "Darwin in placing the extreme depth of flourishing banks of surface-red corals at 25 fathoms was entirely correct. The specimens of these corals procured from beyond this depth show clearly in their growth that the increased depth is deleterious to them. At the same time the presence of a series of other genera of corals, which evidently flourish just beyond where the surface forms cease to exist, although with a considerable range in depth, is for the first time clearly demonstrated."

Mr. Gardiner had unusually favorable opportunities for studying the rate of growth of reefs and reaches a conclusion widely different from Dana's, who considered five feet in 1000 years an average. "Considering all the various factors, and particularly

remembering the necessarily slower growth at the initiation of a reef and as it approaches close to the surface, it yet seems to me to be probable that an oceanic shoal at a depth of 25 fathoms might well in 1000 years, or even less, be covered with a perfect surface reef, built up by nullipores and reef corals. Should these deductions be, as I believe, fairly accurate, a natural explanation is at once afforded of the rarity of submerged banks of all sorts in coral-reef areas as compared with surface atolls and reefs."

III. Miscellaneous Scientific Intelligence.

1. *Report of the Secretary of the Smithsonian Institution for the Year ending June 30, 1902.*—In his annual report Professor Langley gives a summary of the work done by the Smithsonian Institution in its several fields of activity. The appendixes contain detailed descriptions regarding the National Museum, the Bureau of Ethnology, the National Zoölogical Park, the Astrophysical Observatory, etc. The National Museum now contains five and a half million specimens and a new building is urgently needed. The Bureau of Ethnology is preparing a dictionary of Indian tribes as a preliminary step toward the publication of a complete encyclopedia on that subject. In the field work special attention was devoted to the study of aboriginal building irrigation and food sources. The number of libraries and individuals who are participants in the Exchange Service is now 38,200 in 154 countries. During the past year the researches carried on by the Astrophysical Observatory have mainly been concerned with determining the amount and nature of the absorption of solar radiation in the earth's atmosphere and in the solar envelope. These researches are preliminary to and form an essential part of the measurement of the total radiation of the sun. The bolometer has been perfected to measure less than one-hundred-millionths of a degree and "this almost infinitesimal amount is distinguished with readiness and precision." A successful method of overcoming the effects of "boiling" in a telescopic image is announced. (See this Journal, xv, 89.)

Obituary.

Professor Estevan Antonio Fuertes, head of the College of Civil Engineering at Cornell University, died January 23 at the age of sixty-four.

Dr. Charles J. Bell, professor of chemistry in the University of Minnesota, died on January 4, aged forty-eight years.

Dr. Antonio d'Achiardi, professor of mineralogy and geology at the University of Pisa, has died recently at the age of sixty-three.

Sir George Gabriel Stokes, the eminent mathematician, died on February 1, in his eighty-fourth year.

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NOW ON SALE.

The first installment of the Collection of Wm. G. Rothe of Brooklyn has just been placed on sale. It embraces upwards of 900 choice minerals from 1 to 269 in Dana's classification, the native elements, sulphides, chlorides and oxides. A few of the many noteworthy specimens are the following:

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Hessite. One especially choice group of crystals.
Chalcocite. A most excellent series of groups from Bristol.
Cinnabar. Very fine crystallized specimens.
Millerite. Some of the best velvety specimens from Gap Mine.
Chalcopyrite. Gorgeous, iridescent groups, French Creek.
Pyrite. Perfect octahedrons from French Creek.
Smaltite. A wonderfully fine group of crystals.
Calaverite in matrix groups of sharp, brilliant crystals.
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Fluorite. Many very beautiful and rare groups.

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A small selection of superfine Pyromorphites has just arrived from Germany. They are by far the best we have ever had, prices running up to $25.00.

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ART. XXV.—*On the Gaseous Constitution of the H. and K. lines of the Solar Spectrum, together with a discussion of reversed gaseous lines;* by JOHN TROWBRIDGE.

I DESCRIBED in this Journal of July, 1902 and of December, 1902 the discovery of reversed lines in the spectra of gases when the latter are submitted to powerful disruptive discharges. In the first article I spoke of the desirability of obtaining some other material than glass for Geissler tubes in order to determine if any of the lines observed were due to the glass. In this Journal, December, 1902, I described some preliminary experiments with quartz tubes.

In this paper I shall show that the continuous spectra observed when glass tubes are employed are not due to incandescence of the glass walls: and also that the lines obtained by me which coincide closely with the calcium lines at wave lengths 3968 and 3933—H.H. lines of the solar spectrum, are not due to calcium, but are true gaseous lines. The great H. H. lines therefore of the solar spectrum, although being a composite spectrum of many lines, have a basis of gaseous lines. This seems more than reasonable when we consider that the solar protuberances are observed through the great H.H. lines, and when we also take into consideration the rarified nature of the gas and the improbability of a metallic vapor like that of calcium being projected so far from the sun's limb. Moreover I shall show that the reversed lines are due to a solarization of which the Clayden effect is merely a special case.

It was necessary in my work, to determine, in the first place, to what degree metallic electrodes influence the spectra in Geissler tubes of the length and bore which were employed by me. When long and powerful sparks are produced in air, the metallic lines due to the terminals disappear at a distance of

less than two inches from either terminal. The photograph therefore of the spectrum produced by a spark of three or four feet in length, taken at the middle of the spark, shows nothing but air lines, whatever may be the nature of the terminals. Indeed this is true even when sparks of eight inches in length are examined. The most effective way, therefore, of sifting out air lines from metallic spectra is to employ long and very powerful sparks. At one time I believed that the oscillatory nature of the discharge influenced the character of the spectra; I am now of the opinion that introducing self-induction acts by diminishing the energy of the discharge; and that the rate of oscillation has very little if any effect.

In the present paper I shall confine my attention largely to the immediate region of the H.H. lines of the solar spectrum.

In Geissler tubes, also, having capillaries not less than two inches in length, the terminals being three and a half or four inches apart, no metallic lines were observed under the conditions of my work. Indeed, to produce metallic spectra at such distances from the electrodes during the time of duration of the discharges, would demand a prodigious velocity of the metallic particles. I have made a careful study of the influence of metallic electrodes in the tubes employed by me and find no spectra due to them.

In order to determine whether the walls of the glass tubes could give lines due to calcium, I first placed aluminum terminals on a sheet of glass of the same kind as that from which the Geissler tubes were made, and having placed the glass against the slit of the spectroscope I passed powerful discharges of the same nature and energy as were employed in the study of the spectra of gases. The glass was badly corroded along the path of the discharge, showing the same corrosion which was observed in the capillary of the glass Geissler tubes.

No continuous spectrum was observed and no calcium lines. Similar discharges were passed through fifty ohms of No. 36 iron wire; the wire was barely raised to a dull red heat. A photograph was taken of ten centimeters of such wire, illuminated by the discharge from a Geissler tube placed in the same electrical circuit. The photograph showed the wire intact at the moment of the illumination of the tube. It took time to communicate sufficient heat to melt the wire. On the same photograph was shown the subsequent melting of the wire; that is, the wire is seen intact and also the two ends of the wire contorted and burning. If the walls of the capillary of the glass vessels are heated to incandescence, the time element must be large; for the gas must first be heated by the discharge and then the walls of the glass by conduction and radiation. Thermodynamic considerations make it impossible

that the walls of the glass vessels are heated to incandescence; moreover E. Wiedmann* has shown that the heat of electrical discharges in Geissler tubes has been much exaggerated. A photograph was taken of the light from a Geissler tube by means of a rapidly revolving mirror. Besides the tube and in the same circuit was a spark gap between magnesium terminals. The duration of the light of the Geissler tube was one fourth of that of the spark between the magnesium terminals in air. There was absolutely no duration of the light of the Geissler tube due to a supposable incandescence of the glass. The light in the Geissler tube arising from powerful disruptive discharges is the strongest and most instantaneous light which has been obtained and would be useful in the study of rapid motions.

If the glass is not vaporized by the discharges I have employed, the spectrum of calcium cannot be produced in the capillary of the glass vessels. A direct test of the question whether the reversed lines observed by me are due to the glass is afforded by the use of quartz vessels of which the ends were closed by metal plates, there being a complete absence of glass and previous investigation having shown that the metallic plates or terminals gave no metallic spectra. In the case of quartz the powerful disruptive sparks produced absolutely no corrosion of the walls of the quartz capillaries; and the reversed line at approximately wave length 4227 and wave lengths 3968, 3963, H.H. of the solar spectrum came out with the same intensity as in the case when glass was employed. Moreover the strong calcium lines toward the ultra-violet besides those which apparently coincide with the H.H. lines of the solar spectrum were conspicuously absent.

The reversed lines therefore which I described in my previous article and which are shown on the plates of that article are not due to calcium. These lines may arise from an electrical decomposition of residual air. It seems impossible to fill spectrum tubes with perfectly dry and pure hydrogen; traces of air must enter from the purifying and drying apparatus; and the impurities may be brought to light by powerful discharges. I have shown in a previous paper that the electrical decompositions in a tube apparently filled with pure hydrogen can produce various spectra, among them that of argon. The most promising method of obtaining pure dry hydrogen appears to be by the use of liquid hydrogen.

In this Journal for December, 1902, I spoke of a remarkable reversal of lines in the ultra-violet which were obtained by the use of quartz tubes.

Fig. 4 shows these lines with a companion spectrum of magnesium. These reversed lines apparently coincide with spark lines

* Wied. Ann., vi, 1878.

of silicon, in air; and one might conclude that the lines come from a volatilization of the walls of the quartz capillary. There is, however, absolutely no corrosion of the walls of the quartz vessel. The surface of the quartz remains limpid and clear. Fig. 3 shows the same lines, wave lengths 2882, and group from 2542 to 2507. In fig. 3 these lines are not reversed and there is no continuous spectrum. The argument of incandescent walls to account for the continuous spectrum in the case of glass tubes would require a heat of incandescence to volatilize the silicon to produce the bright lines seen in fig. 3. I have concluded that, just as in the case of the supposed calcium lines with the employment of glass tubes, these reversed lines are also due to a gas. In order to discover whether these lines can be obtained from some gaseous constituent of the air, I have studied the spectra obtained from powerful sparks in air taken from a great variety of metallic terminals. The spectra from terminals of pure platinum, electrolytic silver, and iridium show strong lines, which coincide with the dispersion I have employed, with the great H.H. lines of the solar spectrum and also with the gaseous lines I have obtained in rarified hydrogen. Terminals of aluminum, copper, iron, tin, magnesium, do not show these lines, or if at all, very faintly. The noble metals, which are least affected by the electric discharge and which are therefore used for nonoxidizable contact in electric apparatus, give these lines. Is it not probable that when the electric discharge volatilizes to a high degree the electric discharge prefers a passage through the metallic vapor—that is, when short and powerful condenser discharges are employed—and does not sufficiently heat the air to bring out certain air lines. The method of sifting out air lines from metallic spectra by observing the lines which are apparently common to these spectra and setting down such lines as air lines, is a fallacious method. Silicon is not easily volatilizable and certain important groups of lines attributed to that metal, obtained by the use of the spark in air, may be atmospheric lines. I have obtained traces of such lines which seem to coincide with the gaseous lines I obtained with rarified hydrogen in quartz tubes by employing water electrodes. These electrodes were made as follows: two iridium terminals were placed on pieces of kiln-dried wood four inches apart. The condenser spark could leap only one inch. The wood was wrapped with cotton enclosing the metallic terminals; around the cotton was wrapped chamois skin; the clear space between the ends of the wood, thus protected, was half an inch. The terminals thus prepared were soaked in distilled water. A very powerful spark was thus obtained in air: and the spectrum was entirely free from metallic lines. With these terminals it is undoubtedly true that the water vapor conducted the main body

of the discharge just as the metallic vapor does in dry air. The edges of this spark show a strong red tint and give the line spectrum of hydrogen. The center of the spark is of a brilliant whiteness. Strong bands appear in the position of the reversed lines which I have obtained with rarified hydrogen, in the quartz tubes.* There is evidently a chemistry of the electric spark in relation to the appearance of certain lines of the constituents of atmospheric air. The discovery of argon shows this. I am at present working upon this question with still more powerful sparks. The commercial employment of high voltages and great current strength should permit more powerful means in spectrum analysis than have hitherto been employed.

The continuous spectrum observed with disruptive discharges in gases occurs also when electrical discharges are obtained in distilled water and in certain other liquids. Prof. Wilsing,† G. E. Hale,‡ and Lockyer,§ have discussed the reversed lines observed under this condition. The phenomenon of continous spectrum and of reversals obtained by the investigation is, I believe, of the same nature as that observed by me in gases. The continuous spectrum is due to a sudden compression of the medium under the powerful disruptive electrical explosion, and the reversals are due to a solarization and not to a reversing layer. The reversed lines observed by me increase in intensity with repeated discharges. The action appears to be most pronounced toward the ultra-violet. This is the case also with the reversed lines observed under water.

The conclusions, therefore, of my first paper on reversed lines in this Journal for July, 1902, are confirmed by further investigation. At the basis of the great H.H. lines of the solar spectrum there are strong gaseous lines, which I believe are oxygen lines. The reversed lines which apparently coincide with certain calcium lines are not due to calcium but are gaseous.

The phenomena of photographic reversals is of great importance in the study of changes going on in the sun. The accompanying plate show the normal spectra which illustrate this article. Fig. 1 represents the gaseous lines which closely correspond with the great H.H. lines of the solar spectrum. See also fig. 3, in my article in this Journal, July, 1902.

Fig. 2 represents the spectrum of calcium in the neighbor-

* It seems probable that these lines, and also the great H.H. lines of the solar spectrum, are due to oxygen. At very high temperatures the dissociated oxygen may be free to vibrate in its own periods. It does not seem inconceivable, therefore, that many spectral lines attributed to metals may be oxygen lines.

† H. Kayser, l. c., i, p. 228.

‡ G. E. Hale, Astrophys. Jour., xv, 1902.

§ N. Lockyer, Proc. Roy. Soc., lxx, 1902.

hood of the H.H. lines. It is seen that strong lines of calcium are conspicuously absent in fig. 1.

Fig. 3 shows the gaseous lines obtained in a quartz tube

Fig. 1

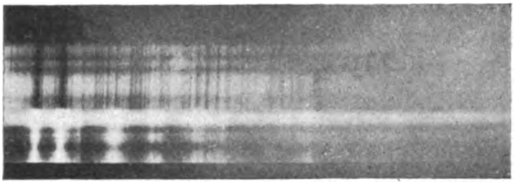


Fig. 2

Fig. 3

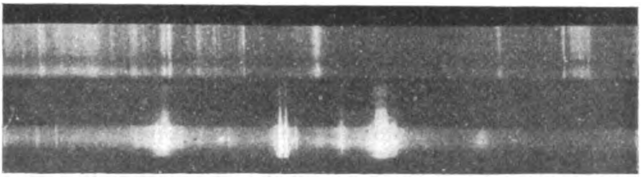
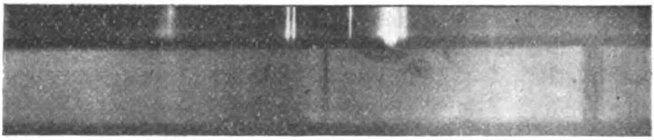


Fig. 4



filled apparently with hydrogen. A strong group of magnesium lines are added for comparison.,

These magnesium lines are the strongest lines of that metal between wave lengths 3000 and 2000.

Fig. 4 gives also the same comparison spectrum of magnesium and reversed lines of the gas contained in the quartz tube.

Jefferson Physical Laboratory, Harvard University.

Art. XXVI.—*The Boys Radiomicrometer;* by C. C. Hutchins.

The following represents the result of many weeks of work spent in the attempt to improve the radiomicrometer, invented by Boys in 1888. If one may judge from notices in the scientific journals, comparatively few have made use of the instrument since its invention. Its simplicity, wonderful sensitiveness, freedom from outside disturbance and other excellent qualities commend it highly, and were it not for the difficulty of preparing the small circuit that is its active and vital part, doubtless it would find a more extended use. Nor is it the mere mechanical difficulties of construction which are here implied; anyone with a fair degree of skill may overcome them, and having done so, it is disheartening to find one's labor in vain—as is very likely to be the case—so frequently do the troubles caused by the magnetic peculiarities of the wire forming the conducting loop make all skill of no avail.

Lewis* made more than seventy-five of these circuits before obtaining a usable one—a record of monumental patience, but hardly calculated to inspire others to begin. The experience of others does not seem to have been very different. The following instance will show how minute are the forces that come into play. A circuit was made from No. 36 copper wire cleaned with fine sand paper. It was found so strongly diamagnetic as to be quite useless. A second circuit was made from the same sample of wire, but cleaned with emery paper that had previously been rubbed upon iron. This circuit proved paramagnetic, and useless for that reason. It will, then, be readily seen how, using ordinary materials, one might spend weeks and never obtain a sufficiently neutral circuit.

If the loop be paramagnetic it sets with its plane parallel to the lines of force of the magnetic field and has a short period of vibration, and the instrument is consequently insensitive. If, on the other hand, it be diamagnetic, it sets with the plane of the loop at right angles to the lines of force. If now it be constrained by torsion of the suspension to take its proper direction, unless it be very strongly diamagnetic, it does not return at once to its position of equilibrium, but drifts back and forth without ever coming to rest, and only after some minutes or some hours returns to the position from which it was disturbed.

Many variations of the above program may be observed, but such is their general behavior as I have observed it, and it

* Standard wave-lengths in the infra red spectra of the elements, Astrophysical Journal, 1895, ii, 1.

would be mere accident or good fortune that one would secure a sample of wire yielding a circuit having a stable zero point and a period of, say, ten seconds.

Paschen* used silver wire, which he found diamagnetic, and corrected this in part by drawing it through steel plates. He obtained considerably greater sensitiveness than was obtained by Boys.

Whatever method of construction of the circuit be adopted, the fact that no available material is magnetically neutral, entirely upsets in practice any theory of the instrument that may be formed. For instance, the sensitiveness of the instrument should increase proportionally to the increase of the magnetic field in which the circuit hangs; but, inasmuch as the magnetic disturbance varies as the square of the field strength, diminishing the field strength may increase the sensitiveness; and this follows whether the material of the loop be either dia- or para-magnetic. In one instance, placing an iron rod across the poles of the field magnet increased the sensitiveness of a certain circuit eight or ten times. Lewis† found that a cast-iron magnet might be too strong. Too much care can not be taken to employ a field as weak as other circumstances will allow, the magnetic disturbances diminishing so rapidly with the field strength. These circumstances are: slight sensitiveness, for a neutral circuit, in a weak field, and a limit beyond which the weight of the circuit can not be reduced. For supposing a circuit magnetically neutral, if we employ a weak field we must employ a suspension of little torsion, and meet the increased period of vibration consequent upon the weakening of the suspension, by diminishing the weight of the circuit. This last has the advantage of removing a portion of the disturbing element, so that, in the end, the stability and sensitiveness of the circuit will depend upon how light it can be made, as well as upon the character of the material that enters into it.

I purpose now to offer a construction which, in my hands, has never failed to produce satisfactory results, yielding very light circuits of great sensitiveness and stable zero point.

Preparation of Bars for the Thermal Junction.—Two alloys are prepared,‡ first, bismuth containing 2 per cent of antimony; and the second, bismuth containing 10 per cent tin. Usually much trouble is experienced in working these brittle metals into fine bars. It is easily accomplished as follows: A quantity of the metal is melted, made very hot, a small pool poured upon a sheet of smoked glass, and a second piece of

* Wied. Ann., xlviii, 272 (1893). † Loc. cit.

‡ C. C. Hutchins, Thermo-electric heights of bismuth and antimony alloys, this Journal, xlviii, 226 (1894).

smoked glass pressed quickly upon it. In this way the metal is pressed while melted into a thin leaf. I have sometimes succeeded in producing leaves of the bismuth-tin alloy as thin as $0{\cdot}02^{mm}$. They are commonly, however, much thicker.

A sound bit of one of these leaves, if too thick, is worked down under the finger upon fine sand paper. No trouble will be found in so making a plate as thin as $0{\cdot}04^{mm}$, and no particular care is demanded. Very narrow bars may be cut from the plate by laying it upon glass, covering as narrow a portion as is desired with a second bit of glass, and cutting off the projecting part by repeated strokes of a sharp knife or graver. By this method of proceeding the bars are rapidly produced, and half an hour suffices for making a supply. The electrical resistance of these alloys is so high that they are easily made too thin; $0{\cdot}06^{mm}$ to $0{\cdot}07^{mm}$ will be found better than thinner, and bars of this thickness may have a length of 6^{mm} to 10^{mm}, and a breadth of $0{\cdot}25^{mm}$ to $0{\cdot}5^{mm}$, according to the remaining dimensions of the circuit.

The Conducting Loop.—With a view to obtaining uniformity of composition, extreme lightness and rigidity, the conducting loop is prepared as follows: Some pieces of soft brass wire No. 27 are well cleaned and silver-plated in a bath of pure silver cyanide dissolved in potassium cyanide. A weak current should be used to insure an even deposit, and the wires should be occasionally removed from the bath and rubbed with crocus-cloth. The deposit may be allowed to reach a thickness of $0{\cdot}04^{mm}$, when the wires are washed and dried.

One of these wires is now bent into a loop of the form and dimensions desired for the finished article; then laid flat and the silver coating filed away on either side. The loop is now suspended from a platinum wire in warm hydrochloric acid, and the brass soon dissolving, there remain two beautiful loops of pure silver, one from the outer and one from the inner parts of the wire. It is evident that the peculiar sectional shape of these loops gives them great lateral rigidity, so that they can be made three to five times lighter than a No. 36 wire, and retain their shape and permit of easy handling.

In the same way loops may be made of copper, by plating upon an aluminum wire, or of gold; but I have found the silver most satisfactory.

Assembling the Circuit.—Having now the bismuth and antimony bars and the conducting loops, we select a pair of the former as nearly alike as possible, and solder one end of each to a disc of thin copper foil 1^{mm} to 2^{mm} in diameter, one bar on either side of the disc and near its edge. The bars should lie just parallel. A thin scale of mica is pushed between them, the silver loop brought into place and soldered. The soldering

is the only difficult part of the whole construction, and will probably try the hand and patience of the beginner. A magnifying glass is of assistance, and a very sharp-pointed tool should be used. Of course, only the minutest quantity of solder is permissible. A solder having a low melting point is desirable, and I have found an alloy of tin, bismuth, cadmium and lead, melting at about 80°, in every way suitable.

The circuit being successfully assembled, the mica is removed, and it only remains to thin the silver loop by holding it for a moment in strong nitric acid and quickly transferring to clean water. This process may be repeated, and the thinning carried beyond the point at which the surface tension will hold the sides of the loop together when it is lifted from the water. When thus made very thin indeed, it is well washed in water and in alcohol, and completed by blackening the little copper disc with Chinese ink, or drop-black. Instead of soldering a wire to the top of the loop for attaching it to the mirror staff, I have found it better to furnish the latter with a flattened hook upon which to hang the circuit. Thus it may be readily taken off for alteration, or another circuit substituted, while in no way disturbing the suspension.

The Mirror.—The mirror is made as usual by cutting a small square or oblong from a silvered microscope cover-glass. It was after condemning as worthless several excellent circuits that I learned that the mirror was causing the trouble. The quartz suspension was very fine, and after removing the circuit from its hook, four complete turns of the fiber were required to sensibly alter the position of the mirror alone. Not all mirrors may be as magnetic as this, but when we are dealing with such minute forces too great precaution cannot be taken. A house of soft iron was constructed for the mirror to swing in, and this being done the difficulty was removed.

The Suspension.—Nothing remains now but to suspend the circuit from a very fine quartz fiber, and provision should be made in the instrument for allowing this fiber to be of any length from 10 or 12 down to 1^{cm}. It is advisable to first suspend the circuit in a glass tube or jar, away from magnets, and to test its period of vibration. If this period be less than 20 sec., the fiber is too coarse. Having found a suitable suspension, the circuit is hung in the instrument, when, if all has gone well, the period will not be greatly altered, and the circuit will be completely under the control of the suspension. In case the circuit is slightly magnetic the period will be less than the free period; but if diamagnetic, greater. However it may be, it is easy to adjust the length of the suspension to give any period desired. In one instance a fiber only 8^{mm} long gave a period

of 12 sec.—about as long as can be used unless precautions be taken to shield the instrument from temperature changes.

Condensing Mirror.—For ordinary purposes the instrument is vastly improved by placing behind the copper disc a small silver or platinum mirror about 1^{cm} diameter and the same or less focus. It is mounted upon the end of a metal plug which moves with friction in a metal tube at the back, that is, opposite the heat-receiving opening of the instrument. Heat is received through a diaphragmed tube, whose diameter may be the same as that of the mirror. The advantages of the condensing mirror are: First, it renders the instrument ten to twenty times more sensitive by increasing the effective heat-receiving surface; and, second, the sensitiveness may be instantly changed through wide limits by more or less withdrawing the mirror, the highest degree of sensitiveness corresponding to the position in which the copper disk is just at the focus of the mirror. Under such conditions of temperature change, convective currents, etc. as are found in an ordinary room, it is not to be expected that the zero point of so sensitive an instrument will remain fixed. When using a very sensitive circuit with long period, although it hung in a block of iron a kilo in weight, yet merely breathing in its direction from the distance of a meter or more gave a deflection greater than the length of the scale. I therefore surrounded the heat-receiving tube with a thick jacket of wood, then swathed the whole instrument in many yards of bunting, torn into strips, until the whole became a huge ball.

It is hoped that the above notes will be of assistance to those who may wish to construct and use this most beautiful but very troublesome instrument.

Searles Physical Laboratory,
Bowdoin College, Brunswick, Maine.

ART. XXVII.—*Meteoric Iron from N'Goureyma, near Djenne, Province of Macina, Soudan;** by E. COHEN. (With Plates II–IV.)

THE meteorite that fell on June 15th, 1900, in Soudan near N'Goureyma, north of Koakourou, in the Province of Macina, weighed 37½ kilograms and is roughly of the form of a drop or flat, wedged-shaped mass 57½^{cm} long, with its greatest width 28^{cm}, about one-third of its length. The wedge tapers towards both ends, the sharpened being 3¾^{cm}, and the blunt end 14^{cm} broad, so that the edges appear to be bulged out. This form as a whole, as well as the various scallopings and jagged projections in detail, will be made clear by reference to Plates II and III. Varying between 1 and 9^{cm} in thickness, the mass is so thin as to be bounded practically by only two surfaces which meet in a pretty sharp edge (Plate III, fig. 2): one surface (Plate III, fig. 1) being considerably more convex than the other (Plate II).

From the characteristics of both surfaces it may be concluded with certainty to be a conspicuously "oriented meteorite," of which the flatter side forms the back and the more convex surface the breast. Compared with the breast the back is characterized by shallower, larger, and for the most part elongated depressions, broader and more rounded edges, smoother surfaces, less uneven and somewhat lighter crust, sharper projecting points or tongue-shaped prominences, and coarser drift effect which is confined to the pointed end. The breast has a greater convexity; smaller, deeper and for the most part rounded cavities, with small bowl-shaped formations on the walls, producing a pock-marked appearance; darker and rougher crust; finer and more abundant drift effect, which is most sharply defined toward the thicker end; and an isolated, deep cavity on the shield-shaped part. Undoubtedly, during the passage of the meteorite through the air, the broader part was directed forward. This is shown by the projections and jagged prominences directed toward the pointed end, the orientation of the elongated depressions, the overlapping of the crust and nickeliferous iron at the edges, the course of the general drift effect and the nature of the abrasion; supposing, as I imagine, that this occurred within the atmosphere by air erosion.

The original form may, however, have been much more regular than the present one and may, perhaps, be compared to a flat oval shield whose apex is eccentric and lies near the highest point of the still remaining bulge. The position of the only deep cavity on the bulge has a like significance. It is

*** This meteoric iron is now in the hands of H. Minod, Comptoir Mineralogique et Geologique, 3 Cours des Bastions, Geneva.**

not uncommon to find one or several especially deep cavities at or near the apex of the anterior surface of an oriented meteorite; since, on the part of the surface farthest forward, the incandescent and greatly compressed air has the greatest erosive effect and can there produce the deepest cavities.

It may further be concluded that this shield-shaped mass with eccentric apex moved through the air inclined at an acute angle to the direction of its motion, in which position the direction of the projections and prominences on the back, as well as the general drift-effect, are more readily brought into accord. It has already been mentioned that the drift-effect appears on both surfaces; a fact which apparently has never before been observed. However, on the breast it is much more abundant as well as more regular, and is more sharply defined on the broader part: while on the back it occurs distinctly only on the tapering end. Its occurrence on both faces, and particularly its distribution, is intelligible to me only on the assumption of an inclination of the meteorite to its path; for in a position either parallel or at right angles to the path, the periphery must have encountered both the heating and air erosion in an approximately like manner, and there could scarcely have been such an unlike deformation.

Because of the slenderness of the shield-shaped body, it is highly probable that the entire mass was molten or at least much softened, so that a considerable part was brushed off, and the air, churned into eddies, could produce greater erosion and abrasion than is usually the case. The result was that the entire back, and the part of the breast to the rear, was covered with closely crowded cavities and bowl-shaped depressions. Only that part of the breast farthest forward suffered the usual, almost evenly distributed melting, without any appreciable splitting-off. Had the motion continued somewhat longer, the deformation would apparently have advanced still farther and possibly the entire remaining part of the shield-shaped surface would have vanished.

The total change of form must have been completed by a time during which the velocity of the meteorite was still sufficient for the formation of crest and drift-effect on the newly made surfaces. It must, further, have been completed within such a short period of time that a complete change of front, in consequence of a change in the position of the center of gravity, could not have taken place, since otherwise the drift-effect must have been effaced. It is not impossible, however, that a tilt occurred about an axis perpendicular to the length and lying in the median plane. In the middle of the breast there is an unusually deep cavity which, in every essential character, is distinguished from all the other depressions. If this cavity was produced in the same way as those on the back, then the

part of the meteorite in question must at some time have been likewise most exposed to the eroding action of the compressed air. The two perforations require no special explanation. Where they occur, the meteorite is so thin that the coincidence of normal flat cavities on the breast and back sufficed for their production.

A pronounced peculiarity of N'Goureyma, which one readily observes in examining polished sections, is the enormous number of small troilites and their regular arrangement, as well as their quite uniform distribution. In sections parallel to the length of the meteorite (Plate IV, fig. 1) these appear mostly as needles, 1½ to 11^{mm} long and ¼ to $1\frac{1}{2}^{mm}$ thick; or as thick-set to elongated bars, sometimes tapering to the finest threads. They also occur in the form of hook-shaped contortions, fork-like bifurcations, ramifications, or wholly irregular forms which, in those of smaller dimensions, diminish to mere points. Whenever, in the section under consideration, there is a club-like arrangement, the thicker end always lies toward the pointed end of the meteorite, as though the troilite had been drawn out in the direction of the motion.

In sections at right angles to the length of the wedge (Plate IV, fig. 2), on the other hand, the troilite stems invariably occur in cross section, showing the greatest variety of forms. Very frequently they are rounded or, when larger, elliptical. In either case the troilites are sometimes compact, sometimes in the form of a hollow cylinder, the walls varying from 0·1 to $0·3^{mm}$ in thickness, filled with nickeliferous iron. Occasionally, however, the latter is divided into two equal parts by a thin portion of troilite; or sundry isolated cylinders of iron occur in the troilite. Four of the latter, for example, were observed in a troilite cylinder of $5/4^{mm}$ diameter. Other sections show forms resembling crescents, horseshoes, sickles, hooks, Ts, masses shaped like clubs or tadpoles tapering to threads of $0·05^{mm}$ diameter, and are sometimes fashioned into various strange hieroglyphics, such as occasionally appear in schreibersite, but, so far as my knowledge extends, have never heretofore been observed in the troilite of any meteoric iron.

These forms on the two sections at right angles to each other show that all the troilites are extended in the same direction and are parallel; forming an arrangement closely resembling the fluid structure of terrestrial rocks. One can best form an opinion of the entirely unusual number of enclosures, which of course are in part very small, when I state that I have counted over 150 troilites on a surface of $12^{sq\ cm}$ and that there is scarcely a surface of $0·5^{sq\ cm}$ to be found in which they are entirely lacking. The distribution on any cross section is always pretty uniform; the total number, however, diminishes appreciably toward the pointed end of the meteorite, as though

the troilite had been crowded back through the softened mass during the flight, or worked up in consequence of their low specific gravity. It may also be especially emphasized that there is an entire lack of any perceptible association with daubreelite, graphite or schreibersite, as well as of nodules of larger dimensions, such as usually prevail in iron rich in troilite.

Schreibersite is unusually sparsely represented in these sections. In most of them it is entirely lacking, and only the largest sections, of $148^{sq\ cm}$, contained, directly under the burned crust or near it, lamellæ of which the largest was 3^{cm} long and 2^{mm} thick.

Observation of the unetched sections alone show that N'Goureyma belongs to the comparatively rare group of coarsely granular irons. The fractures marking the limits of the granules, however, as usual, are brought out more distinctly and completely by etching, which makes them broader and deeper. Isolated fractures open to a width of $\frac{3}{4}^{mm}$; others are so small as to be perceived only under the microscope. Occasionally the fractures are found to be filled up with troilite, the separation of which must have continued after the formation of the fractures, although the fluid arrangement justifies the conclusion that the main separation had occurred earlier; these granular components are bounded by irregular edges, though the majority are in general fairly isometric, with a thickness varying between $1\frac{1}{2}$ and 3^{cm}. Isolated ones diminish to $\frac{1}{2}^{cm}$. Many are elongated, especially the larger ones, which then attain a length of 7^{cm} and a thickness of 2^{cm}. In this respect the five cross sections are exactly alike. The section made from a tongue-shaped projection (Plate IV, fig. 2) appears, however, to be an individual; evidently a single granule which has been drawn out in the direction of the longitudinal axis of the meteorite; in which case, because of the slenderness of the projection, contraction fractures (perhaps parallel to the section) would certainly not be at all obvious.

Etching develops glistening plates (Plate IV, figs. 1 and 2), the arrangement of which is suggestive of Widmanstätten figures. Under the microscope, however, one sees that there are really no connected lamellæ at all, but that tiny spangles or granules, better reflecting than the remaining nickeliferous iron, collect in indistinctly defined and small elongated clusters, arranged in more or less connected rows which intersect in groups. At any rate, there is nothing perceivable under the microscope which could suggest the kamacite blades and their taenit fringes found in normal octahedrite. The remaining nickeliferous iron, which perhaps is plessite, appears to predominate in places and then again to be less prominent; always, however, forming a coherent body like the nickeliferous iron of compact ataxite.

Such peculiarities of structure are unknown to me in any other meteoric iron. It seems to me quite plausible that this was originally a coarsely granular octahedrite, like Zacatecas, which in consequence of its very flat form softened throughout its mass, perhaps to the melting point, as it entered the atmosphere. In the subsequent rapid cooling there was not time enough for a normal crystallization—formation of octahedral lamellæ. Alloys rich in nickel could not unite so as to form symmetrical taenit lamellæ; but, during precipitate crystallization, separated into the finest spangles which in their habit arranged themselves so as to be oriented parallel to the octahedral planes, while the remainder uniformly solidified to a compact plessite-like nickeliferous iron.

This assumption of the softening or melting of the entire mass of the meteorite, however unusual, is supported by a large number of phenomena which, up to the present, have never been observed in any other iron. Among these peculiarities are:—the fluid arrangement of the troilite; the absence of larger nodules, despite the unusual richness in sulphide of iron; the lack of an alteration zone, along with the possession of a completely fused crust; the tapering and tongue-shaped projectious, extended in the same direction; the pointed, wedge-like shape; the unusually varied and in part bizarre relief of the anterior surface; the perforations, which cannot be attributed to the melting out of accessory ingredients; and the increased richness in troilites toward the part of the meteorite which was rearmost in the course of the flight.

I consider that these phenomena prove N'Goureyma to be a member of the Zacatecas group, which was remelted during its passage through the air, and may be considered as a sort of appendage to this group. The unusual richness in sulphide of iron, moreover, could have had an influence on the disturbed crystallization, just as in Zacatecas, rich in troilite, the octahedral structure is less complete than in most of the normal octahedrites.

The analysis which I have made gave the following results:—

Fe	89·28	Nickeliferous iron	97·28
Ni	9·26	Schreibersite	0·32
Co	0·60	Troilite	1·75
Cu	0·04	Daubreelite	0·30
Cr	0·11	Lawrencite	0·02
S	0·77	Chromite	0·09
P	0·05	Decomposed silicious grains	0·24
C	0·04		
Cl	0·01		100·00
Chromite	0·09	Specific gravity is 7·672	
Residue	0·24		
	100·49		

Greifswald, Germany.

About 2/5 nat. Size

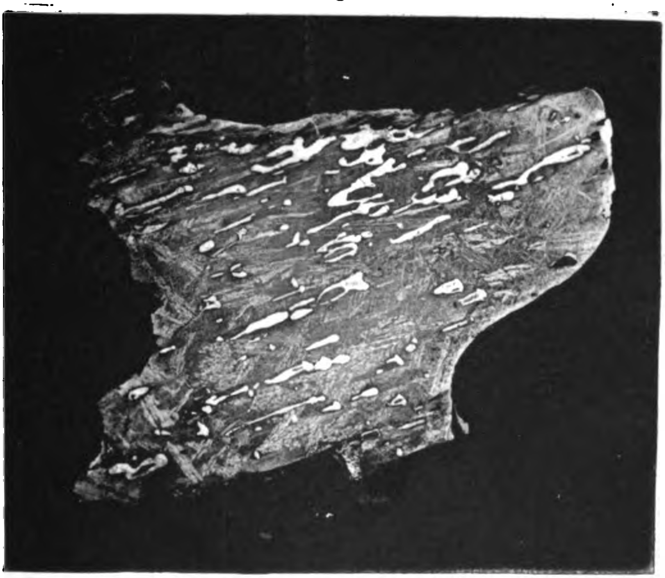
Meteoric Iron from N'Goureyma

(The Property of the Comptoir minéralogique et géologique suisse, Geneva)

Fig. 1

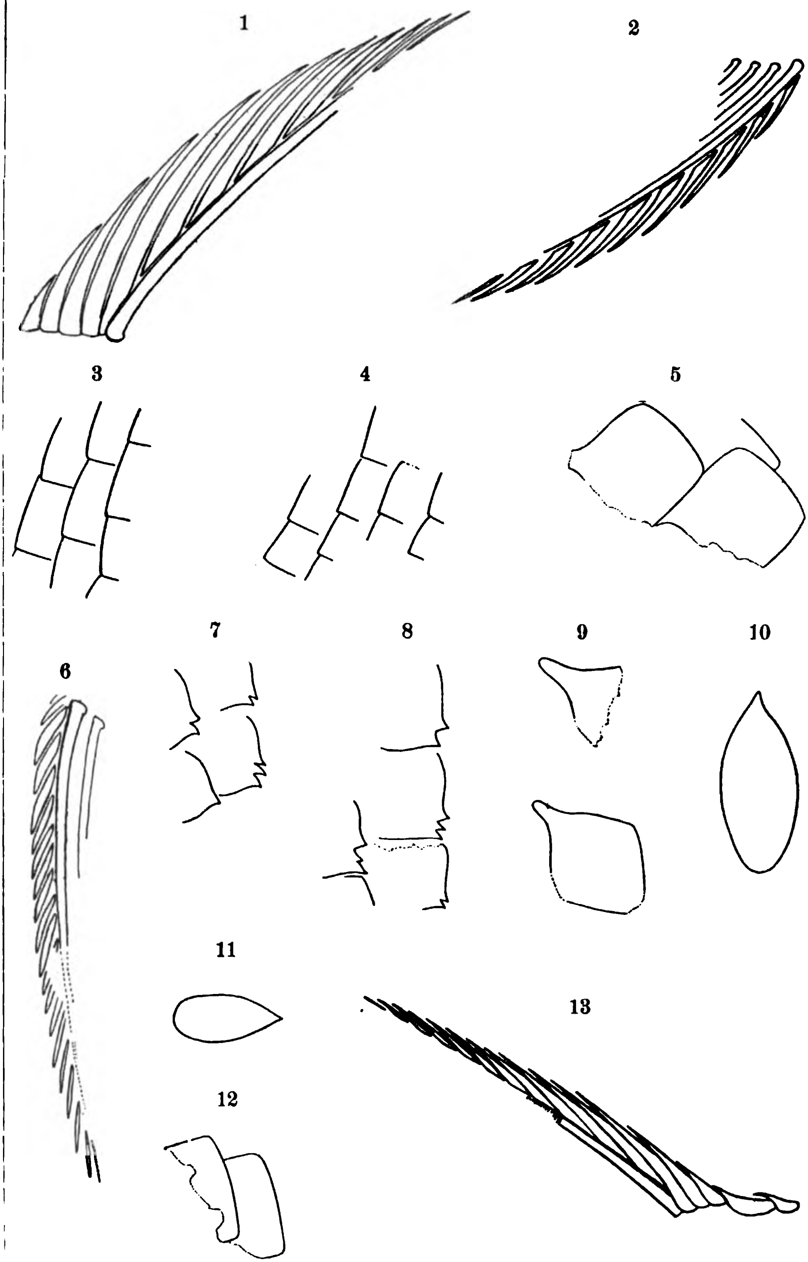
16/11 nat. Size

Fig. 2



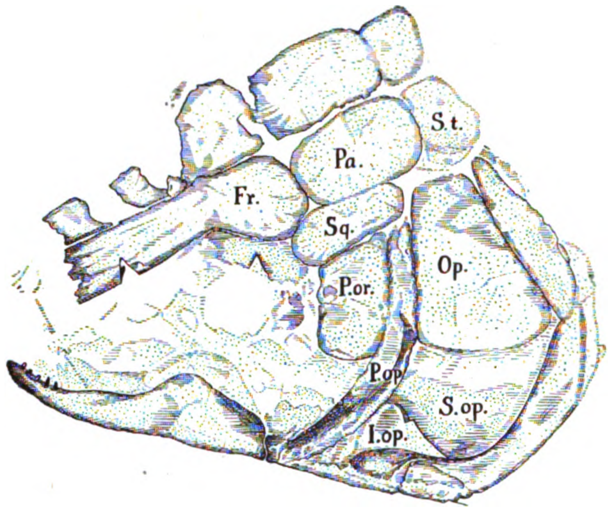
4/3 nat. Size

Meteoric Iron from N'Goureyma



TRIASSIC FISHES.

1



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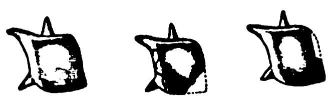
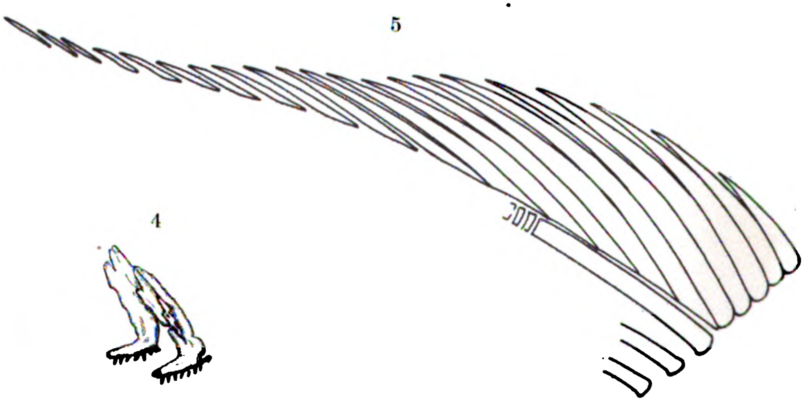


5



4

Triassic Fishes.

ART. XXVIII.—*Notes on the Collection of Triassic Fishes at Yale;* by G. F. EATON. (With Plates V and VI.)

IN 1870 the collection of Triassic fishes made by Messrs. W. C. and J. H. Redfield, and generally known as the "Redfield Collection," was presented to the Yale Museum, with the understanding that it should be arranged and placed on exhibition as soon as opportunity served. The gift was acknowledged in the annual report of the Sheffield Scientific School, 1870–71; but for various reasons most of the specimens remained unexamined in the store-rooms of the museum for nearly thirty years. Meanwhile, good material of the same geological age, received from other sources, has greatly enhanced the value of the Yale collections.

Semionotus.

In preparing these Triassic fishes for exhibition, an attempt was made to follow Prof. Newberry's classification, as proposed in his monograph on the Triassic Fishes and Plants.* His arrangement, however, was not found entirely satisfactory. Especially was this the case in regard to the genus *Semionotus (Ischypterus)*, under which some of the specific definitions are uncertain guides in identifying specimens, because of the lack of characters offering any real contrast between the different species named. Fortunately most of Prof. Newberry's types are preserved in the Yale University Museum and in the Columbia University Museum. After a careful study of these and of all other accessible material, the present writer has been enabled to state additional characters to some of the species described in Prof. Newberry's work; while, on the other hand, it still seems advisable to leave many forms in the doubtful list to which they were relegated by Dr. A. Smith Woodward.† Indeed it appears probable that Prof. Newberry's enthusiasm led him to describe more species than are now warranted by the better and larger collections available for study. Well aware of the difficulties he encountered in classifying such imperfect and indistinctly preserved material as the American Triassic fishes, Prof. Newberry himself graciously made easier the task of reducing the number of species by stating that intermediate forms might ultimately make reduction necessary. It is significant that in Dr. Woodward's Catalogue, only two of the American species are deemed worthy of description under the genus *Semionotus* (synonymous with *Ischypterus*), the remainder being merely listed as doubtful and probably

* Mon. U. S. Geol. Surv., No. xiv, 1888.

† Cat. Foss. Fish., British Mus. Nat. Hist., pt. iii.

based on inadequate material. It is to be regretted that Dr. Woodward had not an opportunity for a thorough revision of the American species of this genus. His decision to unite *Ischypterus* with *Semionotus* is satisfactorily borne out by the investigations of Dr. E. Schellwien, recorded in his valuable monograph.*

At the outset the question arises—what characters should be chosen for the basis of classification? Prof. Newberry placed much confidence in proportional length and depth. Dr. Woodward, relying on these proportions and also upon scale conditions, recognized, as stated above, only two American species of *Semionotus*. Although he has thus taught a wholesome and well-deserved lesson, he has probably been too severe in his judgment upon the work of American authors. Even granting that the cranial and facial bones originally possessed specific differences, it would be a profitless task to base the classification of the various species upon such characters, obscured as they now are throughout nearly the whole series of specimens. To the present writer the only safe course out of the difficulty seems to be to arrange this group of fishes mainly according to the character of the fins and scales, and when these are indistinct not to attempt the specific identification. Strict adherence to this method has resulted in the revision of species offered in this paper.

The search for specific characters has, however, led to something of greater interest. A specimen of *S. Marshi* from Sunderland, Mass., has been prepared in which the head bones are so clearly defined that an accurate drawing can be made of them (Plate VI, fig. 1). Although the bones of the maxillary arch and of the circumorbital series cannot be recognized, and the post-temporals are obscure, in other respects the preservation is remarkably good, and the forms of the bones which have been drawn may be considered fairly characteristic of the genus. The premaxillaries, which are lacking in this example, are shown distinctly in an otherwise poor specimen of *Semionotus* from Boonton, N. J. (Plate VI, fig. 4), whose specific identification is uncertain. In the figure of this latter specimen the left premaxillary is seen in advance of the right, and the paradoxical overlapping of the ascending process of the right premaxillary by that of the left probably resulted from maceration. In order to expose the entire premaxillaries it was necessary to remove part of the right frontal. Apparently, during life, the frontals overlay the upper third of the ascending processes of the premaxillaries.

With the drawing of the head bones it may be well to record

* "Über Semionotus Ag.," Königsberg in Pr., 1901.

here some characters of the scales which have not been emphasized by previous writers. The most handsome and complete specimens do not generally show the form of the overlapped portions of the scales. Such details are occasionally to be seen in the dissociated scales of fragmentary specimens. Unfortunately the same conditions which make this possible may also render the specific identification difficult and uncertain. Slightly at variance with Dr. Woodward's statement in regard to the scales,* "the narrow overlapped margin not produced at the angles," most of the American species show the antero-superior angle of the lower flank scales produced to a marked degree, and there is reason to suppose that this character holds good throughout the American division of the genus. Not only is the "peg-and-socket articulation" found in the flank scales generally, the pegs extending upward from the superior border of the scales, but the present writer has prepared for the Yale Museum an example of *Semionotus* from Boonton, N. J., in which the lower flank scales of the ventral region articulate by a second series of pegs and sockets (Plate VI, fig. 3). The antero-inferior angles of these scales bear peg-like processes, similar in size and form to those of the upper border, which lie under the posterior margins of the adjacent scales. The specimen displaying this double articulation is of uncertain specific identity, and it would be quite useless, at present, to speculate upon the prevalence of this character throughout the genus.

Semionotus fultus Agassiz.

Palæoniscus fultus L. Agassiz, 1833, Poiss. Foss., vol. ii, pt. i.
Palæoniscus fultus W. C. Redfield, 1841, This Journal. vol. xli.
Palæoniscus macropterus W. C. Redfield, 1841, ibid.
Ischypterus fultus Sir P. Egerton, 1847, Quart. Jour. Geol. Soc., vol. iii.
Ischypterus fultus J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.
Ischypterus macropterus J. S. Newberry, 1888, ibid.
Semionotus fultus A. S. Woodward, 1895, Cat. Foss. Fish., British Mus. Nat. Hist., pt. iii.

A number of specimens seeming to Prof. Newberry to offer slight differences in the proportions of length and depth were arranged by him in two species—*Ischypterus fultus* and *I. macropterus*. These specific names had been used previously, their history being as follows: In 1833 *Palæoniscus fultus* was given by Agassiz, in his *Poissons Fossiles*, to small and imperfect specimens from Sunderland, Mass. The species was afterwards placed in the new genus *Ischypterus*, by Sir Philip Egerton.† Meanwhile, the name *Palæoniscus fultus* was applied to specimens from Massachusetts, Connecticut, and

* Loc. cit.

† Quart. Jour. Geol. Soc., vol. iii, 1847.

New Jersey, by W. C. Redfield,* who at the same time gave the name *P. macropterus* to specimens from these localities. It appears that there was some doubt as to the validity of the latter species, for, in 1848, a paper by J. H. Redfield was read before the Association of American Geologists and Naturalists, in which *I. fultus* and *I. macropterus* were discussed and were united under the name *I. fultus*. The late Prof. Newberry, belonging to a school of paleontologists whose practice it was to decide all doubtful cases in favor of new species, again separated the two forms; and finally Dr. Woodward (loc. cit.) reunited *I. macropterus* with *I. fultus*, and placed the latter in the genus *Semionotus*, where it will doubtless remain, for no generic difference has been shown between the American *Ischypterus* and the Old World *Semionotus* established by Agassiz in 1832.

The only character of *Semionotus macropterus*, as described by Prof. Newberry, that separates it from *S. fultus* is its relatively greater depth† of body. Even this the author did not state with much assurance, for after discussing the two species at length without contrasting them, he used the following words: "In most cases, however, there need be no doubt, the fusiform and slender fish standing for *I. fultus*, the broader one for *I. macropterus*." A careful examination of Prof. Newberry's original collection at Columbia University shows that, while one of the specimens (not a type) of *I. macropterus*, in its pressed and flattened condition, is deeper than a type of *I. fultus*, all the others are proportionately more slender. For this reason Dr. Woodward's decision will be adopted, and the specimens in the Yale Museum which have hitherto been labeled *I. fultus* and *I. macropterus* will now be exhibited under the name *Semionotus fultus*. The following description, while not as clear as could be desired, is as detailed as the condition of the fossils permits; and it will serve, at least, to distinguish good examples of *S. fultus* from well-preserved specimens of the other species:

S. fultus, attaining a length of 9 inches and a depth of $2\frac{1}{2}$ inches. Origin of dorsal fin at mid-length.

Origin of anal fin under middle of dorsal fin or somewhat further to the rear, and on the third oblique scale-row in advance of the dorsal fin.

Origin of ventral fins slightly nearer to anal fin than to pectoral fins.

Dorsal fin fulcra about 12, rays about 10 (Plate V, fig. 1).

Anal fin fulcra about 12, rays about 10.

Dorsal and anal fin fulcra long. Apparently 4 dorsal fulcra

* This Journal, 1841.

† Termed "broader" by Newberry.

originate on the dorsal line over basal supports. The 5th dorsal fulcrum has its origin adjacent to that of the 1st ray, and is about equal in length to one-half the anterior margin of the fin.

Pectoral fins show, on the superior surface, about 10 fulcra, long and slender, and not widely divergent from the rays, which are about 10 in number (Plate V, fig. 2).

Ventral fins show, on the superior surface, about 10 fulcra.

Caudal fin has about 15 rays.

The best preserved specimens are a little less than four times as long as deep, the maximum depth being midway between head and dorsal fin, where the oblique scale-row comprises about 20 scales. Horizontal scale-row along lateral line comprises about 33 scales.

The deepest scales are in the 4th row behind the clavicular arch; these are twice as deep as long.* Scales of the anterior caudal region are nearly equilateral. With the exception of the scales of the lateral line, the anterior flank scales generally have the postero-inferior angles slightly rounded (Plate V, fig. 3), and the posterior flank scales have the postero-inferior angles produced into single points (Plate V, fig. 4). In rare and doubtful cases, the posterior borders of the flank scales may be slightly irregular, but never to the extent commonly seen in *S. micropterus.*

Semionotus micropterus Newberry.

Ischypterus micropterus J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.

One of the fishes placed by Dr. Woodward in his list of doubtful species is *S. micropterus.* It is encouraging to find that good specimens, not accessible when his Catalogue was compiled, now make it possible to describe this species more fully and to separate it from other forms by the characters of its fins and scales, and not solely by its contour. This species may be described as follows:

S. micropterus, attaining a length of 10 inches and a depth of 3 inches.

Relative position and size of fins about the same as in *S. fultus.*

Dorsal fin fulcra about 14, rays about 9 (Plate V, fig. 13).

Anal fin fulcra about 14, rays about 9.

Dorsal and anal fin fulcra relatively shorter than in *S. fultus.* Apparently 3 dorsal fulcra originate on the dorsal line over basal supports. The 5th dorsal fulcrum has its origin on the anterior margin of the 1st ray, at a point considerably removed

*These and similar measurements refer to the exposed portion of the scales, not to actual dimensions.

from the origin of that ray, and is about equal in length to one-third the anterior margin of the fin.

Pectoral fins show, on the superior surface, about 17 fulcra, which are shorter than in *S. fultus* and other species (Plate V, fig. 6).

The last scale of the anterior dorsal ridge has its posterior end slightly produced into a point (Plate V, fig. 11).

The best preserved specimens are a little more than three times as long as deep, and have a more strongly convex outline in the pectoral region than *S. fultus*.

In the majority of specimens, the flank scales, especially those below the lateral line, show a tendency to become bi- or tri-dentate on the postero-inferior angle (Plate V, figs. 7 and 8). Although this character is not always present, it may serve to identify the species in question, when the dorsal and pectoral fins are not preserved. No other species shows scales thus strongly dentate.

In reference to these dentate scales of *S. micropterus*, it is interesting to note that a specimen of this species, showing this character highly developed, but having the anterior dorsal ridge (characteristic of the genus) concealed, was labeled by Prof. Newberry "*Catopterus Redfieldi*." This error may have been caused by the presence of the "one or more posterior teeth" of the scales, given by Prof. Newberry as a character of *C. Redfieldi*, and also by the form of the pectoral fin fulcra, which offer a slight resemblance to those of *Catopterus*.

Semionotus Marshi W. C. Redfield.

Ischypterus Marshii **W. C. Redfield, 1856, Proc. Am. Assoc. Adv. Sci. (Name only).**

Ischypterus Marshii **J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.**

The Redfield Collection contains an imperfect fish about 12 inches long, from Sunderland, Mass., bearing the name *Ischypterus Marshii*. No description of this fish was published by the Redfields, although the name is found in a paper by W. C. Redfield entitled "On the Relations of the Fossil Fishes of the Sandstone of Connecticut, and other Atlantic States, to the Liassic and Jurassic Periods" (Proc. Am. Assoc. Adv. Sci., 1856). Prof. Newberry's monograph contains a plate and a description of this species, the credit for which is generously given to W. C. Redfield. Three other specimens from Sunderland, undoubtedly belonging to the same species as the above mentioned fish, are in the collection of the American Museum of Natural History in New York. According to the statement of Prof. Whitfield of that museum, their labels, bearing the name *I. Agassizii*, were written at the dictation of Prof. Newberry, when the latter was asked to identify them. This

incident is of especial interest in connection with the discussion of *I. Agassizii* in Prof. Newberry's monograph, where he writes "I have seen no such fishes as these anywhere except at Boonton. * * * At Sunderland occurs another species (*I. Marshii*) which in form and general aspect resembles those under consideration, but it is narrower, with less strong dorsal and anal fins, with thicker and relatively broader scales, which form more oblique rows on the sides. For these reasons I have thought it wise to regard it as distinct."

So far as comparison can be made, the three fishes at the American Museum of Natural History, labeled *I. Agassizii*, agree with the type of *S. Marshi* in size and form of body, size, form, and obliquity of scales, and relative position and structure of fins. The specific description here offered is based upon these specimens jointly with the type at Yale:

Semionotus Marshi, attaining a length of 12½ inches and a depth of 3½ inches.

Relative position and size of fins about the same as in *S. fultus*.

Dorsal fin fulcra about 14, rays about 9.

Anal fin fulcra about 14, rays about 9.

Apparently 4 dorsal fin fulcra originate on the dorsal line over basal supports, the 5th being nearly equal in length to one-half the anterior margin of the fin.

Pectoral fin fulcra about 14, rays about 12.

Ventral fin fulcra about 12.

The flank scales usually have the postero-inferior angles a little less pointed than in *S. fultus* (Plate V, figs. 5 and 12), and have the antero-superior angles continued forward as distinct processes under the overlapping scales (Plate V, fig. 9; Plate VI, fig. 2). The deepest scales are in the 3rd or 4th oblique row behind the clavicular arch; these are about twice as deep as long. Scales near the lateral line under the dorsal fin are equilateral.

The maximum depth is midway between the pectoral and ventral fins, where the oblique rows comprise about 19 scales. Horizontal row along lateral line comprises about 34 scales.

The last scale of the anterior dorsal ridge has its posterior end produced into a fine point (Plate V, fig. 10).

Semionotus tenuiceps Agassiz.

Eurynotus tenuiceps L. Agassiz, 1835, Poiss. Foss., vol. ii, pt. i.
Eurynotus tenuiceps J. H. Redfield, 1837, Ann. Lyc. Nat. Hist. N. Y., vol. iv.
Palæoniscus latus J. H. Redfield, 1837, ibid.
Ischypterus tenuiceps J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.
Semionotus tenuiceps A. S. Woodward, 1895, Cat. Foss. Fish., British Mus. Nat. Hist., pt. iii.

This is one of the two American species of *Semionotus* approved by Dr. Woodward. Except in its young form it may be

easily distinguished from other species by the peculiar development of the scales of the anterior dorsal ridge. Dr. Woodward describes his type in the collection of the Geological Society of London as follows:

"A species attaining a length of about 0·2 [m]. Trunk with a considerably arched dorsal border, the depth of the caudal pedicle more than one-third as great as the maximum depth of the abdominal region. Length of head with opercular apparatus less than the maximum depth of the trunk, and contained four times in the total length of the fish. Fins as in *S. fultus*. Scales smooth and not serrated, those of the middle of the flank in part twice as deep as broad; dorsal ridge-scales large and conspicuous, comparatively obtuse in large specimens."

To this may be added that the last scale of the anterior dorsal ridge has its posterior end blunt and not produced, while the scale on the ventral line immediately in front of the anal fin has its posterior end notched. The ribs are more strongly developed than in other species.

Semionotus ovatus W. C. Redfield.

Palæoniscus ovatus W. C. Redfield, 1841, This Journal, vol, xli.
Ischypterus ovatus Sir P. Egerton, 1850, Quart. Jour. Geol. Soc., vol. vi.
Ischypterus ovatus J. S. Newberry, 1888, Mon. U. S. Geol. Surv., No. xiv.

Several specimens are to be found bearing this name, but, as far as the writer can ascertain, only one, the type at Columbia University, is so well preserved as to afford specific distinction. The only character given hitherto in which this species differs from others is the greater proportionate depth of body midway between the head and dorsal fin. The type specimen, however, shows another character which will probably be found more reliable, viz., a greater number of dorsal and anal fin fulcra than is found in the other American species of this genus.

S. ovatus, length 11 inches, depth 3¾ inches.

Position and size of fins about the same as in *S. fultus*.

Dorsal fin fulcra 21, actually preserved.

Anal fin fulcra 19, actually preserved.

Apparently 5 dorsal fin fulcra originate on the dorsal line, and the 6th is equal in length to a little less than one-half the anterior margin of the fin (Plate VI, fig. 5).

There is much confusion about the localities ascribed to the American species of *Semionotus*. For example, the two imperfect specimens to which Agassiz applied the name *S. fultus* were found at Sunderland, Massachusetts, and specimens in the Redfield Collection, whose original labels were *S. fultus*, have proved to be *S. tenuiceps* from Massachusetts and *S.*

micropterus from Connecticut. It is certain, however, that Prof. Newberry's types of *S. fultus* and *S. macropterus*, illustrated in his monograph, are from Boonton, New Jersey, and that all the specimens in the Redfield Collection which agree with these types are from New Jersey also; indeed it is possible that *S. fultus* of Newberry should be rightly considered as limited to that state.

S. micropterus is known only from Connecticut.

S. Marshi probably occurs in Massachusetts, Connecticut, and New Jersey.

S. tenuiceps is a Massachusetts species which is doubtfully from Connecticut.

S. ovatus (type) is from Boonton, New Jersey.

The other species of *Semionotus* described by Prof. Newberry in his monograph must remain of doubtful validity until their claims for distinction are better supported. Indeed the difficulty of the situation cannot be better shown than by quoting Dr. Woodward's sweeping statement: "Nearly complete fishes, variously crushed and distorted and sometimes imperfectly preserved, have been described from the Trias of North America under the following names. They may be conveniently referred to the genus *Semionotus*, and doubtless represent much fewer species than are here enumerated." Then follows a list of all the American species except *S. fultus* and *S. tenuiceps*. It is the present writer's hope that these notes may serve to reëstablish three of the species thus lately discredited, and may place the classification of this genus on a firmer basis.

Catopterus J. H. Redfield.

This genus is represented in the Yale Collection by J. H. Redfield's type of *C. gracilis* and by a remarkably good series of specimens from the Trias of New Jersey and of the old Connecticut River valley, which probably belong under the type species, as they agree in the main with the characters of that species given by Dr. Woodward. The only addition to the knowledge of the structure of this genus is the determination that the flank scales were interlocked by a single peg-and-socket articulation. From the superior margins of these scales arise pegs similar to those which characterize the superior margins of the flank scales of *Semionotus*; but no articulating processes have been found projecting from the antero-inferior angles. As flank scales can be seen in the closely allied genus *Dictyopyge*, which articulate in a like manner, it is evident that the single peg-and-socket articulation is characteristic of the Catopteridæ.

Yale University, February 24, 1903.

EXPLANATION OF PLATES.

Plate V.

Figure 1.—*Semionotus fultus;* dorsal fin.
Figure 2.—*S. fultus;* pectoral fin.
Figure 3.—*S. fultus;* anterior flank scales.
Figure 4.—*S. fultus;* posterior flank scales.
Figure 5.—*S. Marshi;* scales from 12th oblique row, a little below lateral line.
Figure 6.—*S. micropterus;* pectoral fin.
Figure 7.—*S. micropterus;* anterior flank scales.
Figure 8.—*S. micropterus;* posterior flank scales.
Figure 9.—*S. Marshi;* posterior flank scales.
Figure 10.—*S. Marshi;* last scale of anterior dorsal ridge.
Figure 11.—*S. micropterus;* last scale of anterior dorsal ridge.
Figure 12.—*S. Marshi;* scales of 7th and 8th oblique rows, immediately below lateral line.
Figure 13.—*S. micropterus;* dorsal fin.

All the figures are twice natural size.

Plate VI.

Figure 1.—*S. Marshi;* head; natural size.
Fr., frontal; *Pa.*, parietal; *S.t.*, supratemporal; *Sq.*, squamosal; *P.or.*, postorbital; *Op.*, operculum; *P.op.*, preoperculum; *I.op.*, interoperculum; *S.op.*, suboperculum.
Figure 2.—*S. Marshi;* lower flank scale, showing articular process; natural size.
Figure 3.—*Semionotus*, sp.; lower flank scales, showing double articulation; four times natural size.
Figure 4.—*Semionotus*, sp.; premaxillæ; natural size.
Figure 5.—*S. ovatus*; dorsal fin; twice natural size.

ART. XXIX.—*The Mechanics of Igneous Intrusion;* by REGINALD A. DALY.

CONTENTS.

THE problem of the origin of the igneous rocks is intimately associated with the need for clear definition of all the possible methods according to which chambers now occupied by intrusive bodies may have been prepared to receive their respective magmas. Then the recognition of the relative importance of these methods, in explaining the vast number of such chambers now exposed to the light, becomes a second step in the direction of solving the genetic problem. However, those rock bodies—dikes, sheets or sills and true laccoliths—about the intrusion mechanics of which there is a fair consensus of opinion among geologists, are certainly the least notable as to volume among the intrusive masses of the earth. The enormously more important stocks and allied greater granitic bodies to this day form the subject of controversy which, though well regulated by fact, is as vigorous as in the days of Hutton and Werner.

The "laccolithic" theory of plutonic intrusion.—One school of geologists would extend the laccolithic idea to many, if not most, granitic intrusions. Accordingly, the chambers filled with such igneous masses are interpreted as the products of crustal displacement. The planes of single great faults may, in this way, become the locus of the subterranean eruption of magmas, wedging their way along by hydrostatic or other pressure. The well-known "failure to match" of the heaved and thrown sides permits of the existence of potential cavities filled

with magma during the strong dislocation. Encircling faults leading to the foundering of large blocks of the crust, or to the upward thrust of others, are conceived as affording possible modes of intrusion.* Or, finally, as illustrated in the well-known conclusions of Brögger on the Christiania region, colossal masses of granite have been explained as true, deep-seated laccoliths, parting heavy strata after the manner of the trachyte of the Henry Mountains.† Yet it is clear from a survey of geological literature, that the field evidence for such a view is but negative in the great majority of stocks and so-called "batholiths." Most of them are not true laccoliths, as they characteristically occur in regions of great structural complexity, where igneous contacts have none but the most remote sympathy with the structural planes of any one bedded series. Many are much too large and irregular in form to be explained as the result of single faults or single zones of faulting; and the imagined intersecting faults of the "bysmalith" or of the submerged graben-block have been generally sought for in vain about those greatest of all granitic massifs. For the latter no other interpretation seems possible by the theory outlined. On the other hand, every observer who has even a small acquaintance with crystalline terranes of the sort, is now and again struck with the evidences that the granitic magmas represented in his field of study were far from being passive in the hands of the eruptive Titan. Their general defiance of structure and composition in the invaded formations, the irregular ground-plans, and the huge finger-like projections sent into the country-rocks,‡ which are undisturbed either in dip or strike, are among the familiar phenomena indicating that such magmas actively, aggressively, "made their way in the world" by the irregular removal of the invaded formations. The latter look as if they had been, as it were, corroded on a huge scale.

The "marginal assimilation" theory of plutonic intrusion.—Emphasis has, therefore, been laid by a second school of geologists on a hypothesis of slow caustic action by magmas that have advanced into the overlying earth-crust by their own energetic solvent action on their walls and roofs. Additional evidence for the truth of this contention is sought in the facts of the internal contacts, at which magmas are sometimes seen to be modified by the incorporation of the country-rock. This

* W. C. Brögger, Die Eruptivgest. des Kristianiagebietes, vol. ii, 1895, p. 148; J. P. Iddings, U. S. Geol. Surv., Monograph xxxii, Part 2, 1899, p. 16.

† Op. cit., p. 152.

‡ The author will use this term throughout the paper as a synonym for "invaded formation," meaning the rocks cut by, and in contact with, an intrusive. Mining terminology also gives "roof" and "wall" for the upper and lateral surfaces of contact between intrusive body and invaded formation. This temporary appropriation from a kindred science will prove of convenience in the following discussion.

second view doubtless appeals the more strongly to the majority of those geologists who have actually to do with granitic bodies in the field. In fact, the impression has prevailed among some of them that the "laccolithic theory" is as widely held as it is because of its apparent necessity in the prevailing theory of rock-differentiation. Yet it must be considered as conclusively proved for the great majority of stocks and batholiths investigated, that analysis has not yet shown that the second or "assimilation" theory really meets its own crucial test, the chemical and mineralogical blood-relationship between the average intrusive rock and its country-rock along their mutual contact. Currents within the magma would, of course, tend to remove and diffuse products of assimilation from molar contacts;* but it is extremely doubtful that they could so completely mask the expected results of the process as is over and over again illustrated in nature. No single fact concerning granite, for example, is more striking than its astonishing homogeneity in contact with argillite, limestone, crystalline schist or basic igneous formation—a homogeneity that persists, too, from contact to center of the eruptive. In the very common case where the assimilated product is more acid than the original magma, it would tend to rise through the latter, slowly diffusing in the journey. The upper part of the magma basin should, for that reason, become filled with a mixed magma more siliceous than the original. Heterogeneity, even stronger vertically than horizontally, would be expected in a diorite or gabbro magma cutting crystalline schists, or in a granite magma cutting heavy beds of sandstone or quartzite. True thermal convection currents must, under these conditions, be greatly weakened by the strong differences in density of the original magma and the magma diluted, so to speak, by more siliceous material. In the absence, then, of the only kind of current likely to be set up in the process of cooling and mere caustic solution on molar contacts, the diffusion of the diluted magma would take place only with extreme slowness.† Yet, up to the present time, this consequence of considerable vertical heterogeneity under the stated conditions has not been demonstrated in nature. The recorded field discoveries point, on the contrary, to a distinct failure of the known facts to match the deduction from the theory. The few proved instances of endomorphic changes of magmas by assimilation (e. g., the granite of the Pyrenees described by Lacroix) serve, by their conspicuous

* For ease of reference to the great surfaces of contact between intrusive bodies and the terranes cut by them, as distinguished from the contacts of the corresponding igneous rocks and foreign fragments caught in them, the author again introduces a term not in general use but convenient for temporary employment. The former are called "molar contacts."

† Cf. Becker, this Journal (4), iii, p. 30, 1897.

and exceptional nature, to show that granitic magmas, if they have "made their own way" at all, have usually done so in some manner different from merely assimilating the invaded formations on molar contacts.

In a limited fashion, both theories may be accepted as giving the required explanation of actual occurrences of igneous rocks. But what is to be the final conclusion regarding the much greater family of granitic bodies where the objections to both the laccolithic and assimilation theories are felt in full force? They form a riddle for which the writer has been able to find no solution in the existing literature of intrusion. As a contribution to that old and difficult theme, he offers, in the following pages, a brief outline of certain suggestions which have come to him as a result of field study in New England and Canadian areas of granitic formations.* For the sake of brevity, the hypothesis to be proposed will assume a more general character than that warranted by the discussion of any one area, wherein local facts would have to be related with unnecessary detail.

The Hypothesis of Overhead Stoping† by Deep-seated Magmas.

Believing that assimilation by magmatic action of some kind is responsible for practically all the chambers occupied by those intrusives with which he is more or less intimately acquainted, the writer has sought for field evidence as to whether any other sort of assimilation is possible than that by caustic or solvent action of a magma on its roof and walls. Such information is found in the same internal contact-belt where the general failure to prove solutional absorption of the country rock has been so often reported. Within that belt it is the rule to find often very numerous blocks of the invaded rocks. These have usually the following characteristics: varying size; angular or subangular outlines against the eruptive rock, which is essentially unmodified even close to the contact with each block; sharp contacts with the eruptive, in which the blocks are completely immersed; a normally high crystallinity and increased density as a result of contact metamorphism. Very often they show that they have moved but short distances from the niches they once occupied in wall or roof. The molar contact is similarly sharp. It may preserve, with exceeding definiteness, the sharp corners left when the blocks were rifted off. Passing, now, inwards, it is an equally normal thing to find

* A few paragraphs in the paper are identical with passages in a forthcoming bulletin (No. 209) of the United States Geological Survey on the "Geology of Ascutney Mountain, Vermont."

† A technical mining term meaning to excavate upwards or sideways to remove ore.

the foreign inclusions to become rapidly rarer, until, in the heart of the eruptive area, one may go hundreds of yards or even several miles without discovering any such inclusions. If there are hundreds of them in a given part of the contact-belt at the present surface (evidently a chance section exposed by erosion), the natural inference that there are thousands or millions of others enclosed in the eruptive below the level of the visible contact, is clearly permissible. Another legion of them has been destroyed along with their matrix in that part of the igneous body removed by denudation. It is manifest, further, that the rifting of the blocks has *so far* enlarged the chamber occupied by the eruptive. That is, the walls are, on the average, farther apart because of the rifting. The question arises as to whether the chamber may owe the greater part of its present size to a long continuation of the selfsame process, with a simultaneous removal from the visible chamber of the blocks formerly rifted off. The affirmative answer to this question is the kernel of the hypothesis to be proposed.

Strangely enough, the explanation of the presence of foreign blocks within igneous bodies along the molar contacts and the equally conspicuous rarity of such fragments toward the centers of the bodies, has not been, so far as the writer is aware, adequately discussed anywhere in geological literature. How blocks still close to their former homes in the country rock could be suspended in the magma until crystallization of the latter was complete, and whether the normal effect of their complete immersion would be to permit of their floating upwards or sinking downwards in the magma, are questions not as yet properly answered. It will be seen that these queries are of prime importance to the ensuing hypothesis and that the attempt has been made to answer them by correlating experimental and other data acquired for petrological science within recent years. We may, for the present, assume the generally accepted high liquidity of normal plutonic magmas, though in the sequel certain arguments therefor will be given in brief outline.

The relative densities of holocrystalline, glassy, and molten rock at ordinary atmospheric pressure.—As the foundation of the argument, the very careful and fruitful experiment in the dry fusion of diabase by Barus must be briefly described.*

With a much greater refinement and accuracy of method than that practised by any of his predecessors, Barus has measured the density of a sample of normal diabase at normal pressure (one atmosphere) and temperature (20° C.), and compared therewith the densities of the completely melted rock and of

* Phil. Mag. (5), xxxv, 173 (1893), and U. S. Geol. Surv. Bull. No. 103 (1893). Cf. Joly, on the fusion of basalt, Trans. Roy. Dublin Soc. (2), vi, 298 (1897).

the glass resulting from the rapid cooling of the fused product, both glass and molten rock being again under one atmosphere of pressure. His results are summarized in the following table and list of conclusions from his own more detailed scheme of observations and from his important fusion curve. As it is expedient in the present connection to choose a reference temperature that will be high enough to allow of a degree of superheating of any plutonic rock-type sufficient to keep it molten even under several thousand atmospheres of pressure, the writer has chosen 1400° C. as the basis for comparison of the densities of molten magmas.

TABLE I.

	Temperature.	Volume ratios.	Specific gravities.
Rock	20° C.	100	3·0178
Glass	20°	111·2	2·717
Molten rock	1400°	119·6	2·523

Increase in volume in passing from glass at 20° C. to molten condition at 1400° C.	7·7 %
Increase in volume in passing from glass at 20° C. to melting point at about 1090° C.	2·8 %
Net decrease in specific gravity in passing from rock at 20° C. to glass at 20° C.	10 %
Decrease in specific gravity in passing from glass at 20° C. to molten condition at 1400° C.	7·1 %
Decrease in specific gravity in passing from rock at 20° C. to molten condition at 1400° C.	16·4 %
Decrease in volume in the act of solidifying to a glass	3·9 %

There was a notable and sudden increase in volume at melting. The expansion was steady up to the melting point and again steady, but more rapid after melting than before, being about 1·9 times faster.

Barus also gives a timely explanation of the reason why a fragment of solid diabase will not readily be made to sink in the molten glass of its own substance. He shows that a "boat," made of chilled glass, is instantly formed about the cold fragment as it meets the surface of the fused mass. A full corroboration of his conclusion that such a fragment, once completely submerged in the non-chilled molten glass, must forthwith sink, has been given by Lagorio's experiments.* They also correspond with observations by Johnston-Lavis, who has seen compact lava sink in a liquid flow from Vesuvius.†

A critical comparison of other experimental studies with those of Barus indicates that they fully bear out his conclu-

* Tscher. Min. u. Petrog. Mitth., viii, 510 (1887).

† Quart. Jour. Geol. Soc., xxxviii, Proc., 240 (1882). Cf. Dutton at Kilauea, 4th Ann. Rep. U. S. Geol. Surv., 106 (1884).

sions. Mallet and others have shown reasons for scepticism as to the accuracy of Bischof's early work in fusion, while Gilbert pointed out the patent error of Mallet's own method of criticism.* Forbes found a net expansion of 6·4 per cent in the passage of basalt at 20° C. to glass at the same temperature, but, however accurate, his result is not here of great value as he has given no information as to the degree of vesicularity or crystallinity of the original rock.† These two characters are so important that the further analysis of experiments older than those of Barus, had best be concerned only with those in which only holocrystalline, plutonic rocks or allied crystalline schists were employed in fusion. The most reliable of these known to the writer were made by Delesse‡ and by Cossa.§ Delesse made in all forty-seven fusions, but many of them must, for our present purpose, be discarded because of the vesicularity of the fused products. He measured the densities of the various rocks at normal atmospheric pressure and temperature, and those of their respective glasses under similar conditions. The most reliable of these determinations are entered with those of Cossa in Table II.

TABLE II.

Authority.	Rock type.	Spec. grav. of rock.	Spec. grav. of glass.	Net decrease in density.
Delesse	*Granite*	2·730	2·450	10·26 %
		2·623	2·360	10·03
		2·684	2·423	9·72
		2·680	2·427	9·44
		2·751	2·496	9·27
		2·700	2·447	9·37
		2·660	2·425	8·84
		2·643	2·478	6·24
Cossa	*Syenite*	2·710	2·430	10·33
Cossa	*Quartz diorite*	2·667	2·403	9·90
Delesse	*Diorite*	2·921	2·679	8·29
		2·799	2·608	6·82
		2·858	2·684	6·09
Delesse	*Gabbros*	3·100	2·664	14·06
		2·898	2·641	8·87
Delesse	*Gneiss*	2·821	2·625	6·95

If, now, we bring the averages of the last table into comparison with the results of Barus on diabase, we have Table III:

* Rep. on the Geol. of the Henry Mts., p. 76, Washington (1887).
† Chemical News, Oct. 23, 1868.
‡ Bull. Soc. Géol. France (2), iv, 1380 (1847).
§ Zirkel, Lehrb. d. Petrographie, i, 681 (1893).

TABLE III.

Rock type.	1. Sp. gr. of rock at ca 20° C.	2. Sp. gr. of glass at ca 20° C.	3. Net decrease in density, rock to glass.	4. Net increase in vol., rock to glass.	5. Sp. gr. of rock molten at 1400° C., cal. from Barus's fusion curve.
Diabase of Barus	3·0178	2·717	10·00 %	11·2 %	2·523
Av. gabbro of Delesse	2·999	2·642	11·57	13·1	2·507
Av. diorite "	2·859	2·657	7·07	7·6	2·390
Q. diorite of Cossa	2·667	2·403	9·90	11·1	2·229
Syenite of Cossa	2·710	2·430	10·33	11·5	2·266
Av. granite of Delesse	2·684	2·438	9·16	10·0	2·243
Av. of all above			9·67	10·7	
Gneiss of Delesse	2·821	2·625	6·95	7·5	2·358

The conclusions immediately derivable from columns 3 and 4 are: first, that the results of Barus, Delesse and Cossa on the whole agree closely and are mutually corroborative; secondly, that the net expansion increment of diabase in passing from the holocrystalline to the glassy state (at one atm. pressure), is nearly the average for all plutonic types; thirdly, that the agreement of Barus and Delesse is specially close when the two observers used rocks of nearly equivalent chemical composition; fourthly, that, from the similar behavior of plutonic types within the limits investigated, it is fair to consider it highly probable that all the types would be characterized by nearly the same rate of expansion in passing from the holocrystalline to the molten state at 1400° C., although experimental data be now lacking for testing the justice of that inference. (Col. 5 contains the values of the corresponding specific gravities calculated from Barus's fusion curve as the standard); and, lastly, that, as expected, decreasing acidity means increasing density of the molten magma at 1400° C.

In view of the disturbing influence of vesicularity and of variable crystallinity in his lavas, it appears that Delesse's table showing that thermal expansibility is strongly affected by basicity (fusibility), is unreliable.* In fact, so closely accordant are the various rock-types referred to in Tables II and III, that we may not expect serious error in applying Barus's accurate expansion curve to plutonics generally. The writer has therefore constructed Table IV, in which col. 1 represents the range of specific gravity found in the different chemically analyzed types noted in Rosenbusch's Elemente der Gesteinslehre. Col. 2 represents the range of specific gravity (calculated from the fusion curve) in the same rocks molten at 1400° C. and at normal atmospheric pressure. Col. 3 gives the specific gravities of the same rocks supposed to follow the law of normal

* Op. cit., p. 1390.

expansion (according to the curve) as solid bodies, but at 1400° C. Col. 4 gives the specific gravities under the conditions of col. 3, but calculated from the expansion coefficients of Reade.* It follows from this calculation that, if average sandstone, marble, slate, and granite should expand uniformly as solid bodies to 1400° C. and according to the rates set forth in those coefficients, the rocks would expand respectively 4·2, 4·1, 3·9 and 3·7 per cent in volume. The increase for diabase under similar conditions but calculated from the ratio of expansion in solid diabase as determined by Barus, is 3·6 per cent. These figures and a comparison of cols. 3 and 4 indicate a remarkable agreement in the results of quite independent experiments using different methods. It will be noted that col. 2 is carried out only for the plutonic massive rocks with which we are here chiefly interested. Further, the legitimacy of extending that column to cover the sediments and schists may be questioned, although the isolated experiment of Delesse on gneiss (Table III) seems to show a thermal expansion behavior for gneiss comparable to that of the standard diabase. In the preparation of col. 4, Reade's coefficient of marble was used for the limestone and dolomite, his coefficient of slate for shale and phyllite, and his coefficient of granite used for the other crystalline schists and for the more acid igneous types. In cols. 2 and 3, a minimum of error adheres to the figures for types *a* to *d*, inclusive, which are most nearly allied in composition to diabase.

Table IV.

Rock-type.	1. Range of sp. gr. at 20° C.	2. Range of sp. gr. at 1400° C. (molten).	3. Range of sp. gr. at 1400° C., (solid) from fusion curve.	4. Range of sp. gr. at 1400° C., (solid) from Reade's coefficient.
a. Peridotites	2·90–3·35	2·42–2·80	2·80–3·23	
b. Gabbros	2·80–3·20	2·34–2·68	2·70–3·09	
c. Average gabbro	3·10	2·59	2·99	
d. Diorites	2·70–3·00	2·26–2·51	2·61–2·90	
e. Elaeolite syenites	2·45–2·60	2·06–2·17	2·36–2·51	2·36–2·51
f. Common syenites	2·60–2·86	2·17–2·39	2·51–2·76	2·51–2·76
g. Granites	2·60–2·73	2·17–2·28	2·51–2·63	2·51–2·63
h. Sandstone and quartzite	2·15–2·75		2·07–2·65	2·06–2·64
i. Pure limestone	2·72		2·63	2·62
j. Pure dolomite	2·87		2·77	2·76
k. Shales and clay slates	2·40–2·80		2·31–2·70	2·30–2·69
l. Average phyllite	2·75		2·65	2·64
m. Gneisses	2·60–3·00		2·50–2·90	2·50–2·90
n. Mica schists	2·75–3·10		2·65–2·99	2·65–2·99
o. Amphibolites, etc.,	2·80–3·30		2·70–3·19	2·70–3·19

* Origin of Mountain Ranges, p. 110, 1886.

Influence of plutonic pressures on rock density.—Before drawing any conclusions concerning the possibility of the flotation of foreign blocks of solid rock in a plutonic magma, it is clear that a preliminary and difficult stage of our inquiry must be passed. What influence has pressure at great depths on the *relative* densities of solid blocks and of the liquid magma in which they are immersed? One can hardly doubt that water and mineralizers in depth would increase such differences as those calculated for one atmosphere of pressure and 1400° C.; so that Gilbert's conclusion as to the difficulty of determining the densities of hydrothermally molten magmas need not affect the present argument except in a favorable way.* Since the temperatures of a block and its enclosing magma are practically identical, the final step in deciding on their relative densities in depth is taken, if it can be shown what is the relative compression suffered by the solid and liquid.

Again we must have recourse to the valuable experiments of Barus as those, of any known to the writer, most nearly related to the problem at issue. He concludes, as a net result of his investigations, that "the relation of the melting-point to pressure in case of the normal type of fusion is nearly constant irrespective of the substance operated on. . . . And in the measure in which this is nearly true on passing from the carbon compounds to the thoroughly different silicon compounds, is it more probably true for the same substance changed only as to temperature and pressure. In other words, the relation of melting-point to pressure is presumably linear."† Accepting his inferences as sound, the fact remains that his experiments on thymol, naphthalene and other carbon compounds can throw light on the behavior of silicate magmas in other respects than that cited in the foregoing quotation. This important deduction is corroborated by the proved similarity of silicates and carbon compounds, in (*a*) the linear relation of expansion to increment of temperature in the solid form of each substance, in (*b*) the linear relation of expansion to increment of temperature in the liquid form of each substance, and in (*c*) the sudden leap in volumetric increment in the act of melting at any temperature.‡

Barus further indicates that solid naphthalene is comparable in compressibility with the liquid form of the same substance.§

* Rep. on the Geol. of the Henry Mts., p. 76 (1877).

† Phil. Mag., xxxv, 306 (1893), and U. S. Geol. Surv., Bull. 103, p. 55 (1893); cf. this Journal, xxxviii, 407, 1889, and xlvi, 141 (1893).

‡ Barus and others have shown that even the exceptional type of fusion represented by ice, becomes the normal type as a not high temperature is reached under a condition of great pressure. This Journal, xli, 326 (1891).

§ This Journal, xlii, 140 (1891).

His fusion curves show that, for the same increase of pressure, liquid naphthalene gains in specific gravity about twice as fast as solid naphthalene. The compressibility of a fused silicate rock is probably, then, about twice that of the same rock when solid. But his diabase fusion curve demonstrates that the thermal expansibility of the liquid rock is about 1·9 times as great as that of the solid rock. Thus a block of cold, solid gabbro immersed in a deep-seated molten magma of the same chemical composition, would be less condensed by the pressure than the molten rock, but the effect on relative densities would be partly compensated by any superheating of the magma. It is, moreover, clear from the facts of cols. 1, 3 and 4, Table IV, that, at 1400° C., this different thermal expansibility would occasion but a small difference in the respective ratios of the specific gravities of a solid rock at ordinary temperature and at 1400° C. to the specific gravity of a magma at the latter temperature. The same is doubtless true of compressibility, since that property bears a simple relation to expansibility. The compressibility of glass and of crystalline silicates is known to be very low. The compression suffered by glass, for example, is about ·0000026 of its volume for 1 atm. The weight of even 10,000 meters of rock with an average density of 2·75 would cause a density increase of much less than one per cent in glass. It is therefore probable that the difference of density between magma and immersed block would not be affected through pressure, at the great depth of 10 kilometers, by as much as 1 per cent of the density of either one.

Relative densities of solid and molten rocks under plutonic conditions.—It is perhaps necessary to state that any errors introduced by the application of the expansion coefficients of Barus and Reade to rocks differing from their types, cannot seriously vitiate cols. 3 and 4 in the table; and that the *relative* differences of density signalized in cols. 2 and 3, or 2 and 4, Table IV, will persist practically unchanged, whether the solid rock is immersed at a temperature near its melting point or a couple of hundred degrees above it.

Not with absolute certainty, then, but with high and cumulative probability, we are entitled to use cols. 2 and 3, or 2 and 4, of Table IV as expressing the essential contrast of densities between plutonic magmas and fragments of solid rock rifted off by them from the walls or roof of their respective chambers. The following conclusions are thus possible:

1. A solid block of each igneous rock would sink in its own molten glass.

2. Blocks of the basic eruptive rocks would sink in all of the magmas except in a very basic peridotite.

3. Blocks of the heavier granites and syenites would sink in all magmas except the more basic gabbros and peridotites.

4. Blocks of all the average sediments and schists would sink in any molten magma except the denser gabbros and peridotites.

5. Blocks of many of the sandstones would float in syenitic (trachytic) magma, and argillites would float in the denser kinds of the same magma.

6. The lighter gneisses, argillites, quartz rocks, and probably many limestones, would float in the average gabbro magma, in which, however, the other sediments and schists would sink. This means that the great majority of the solid crystalline schists would be denser than average molten gabbro under plutonic conditions, although the former are about equal in density to molten basic gabbro.

It must be considered, too, that even the densest gabbro or peridotite would tend to become somewhat acidified, and thus lose in specific gravity, when in contact with those same siliceous rocks which alone would float in that magma. Consequently, any immersed blocks would tend to sink to a greater or less depth depending on the extent of the acidification. Secondly, the normal increase of density due to the contact metamorphism of siliceous and calcareous sediments and many crystalline schists invaded by hypogeal magma, must add to the likelihood that detached blocks from the country rocks could not remain in suspension in the magma. How significant can be the density increment due to exomorphic changes is illustrated in Rosenbusch's classic researches in the Steiger Schiefer, in Gilbert's account of the contact action about the Henry Mountains laccoliths, and in a great number of other studies to which further reference is unnecessary.

Fluidity of plutonic magmas.—Brögger has summarized most of the arguments for the general high liquidity of granitic and other deep-seated magmas.* They are so convincing that this question, postponed from an earlier stage in the present line of thought, need not detain us long. The known attributes of those portions of such magmas as reach the surface of the earth as lavas, and the common abundance of thin but often remarkably long, apophysal sheets and dikes from the main intrusive bodies, are facts too well established to permit of essential doubt as to high fluidity. Nothing can seem more probable than that the relatively small fall in temperature, represented in the passage of a thinly molten magma to a toughly viscous condition, has actually taken place in plutonic bodies. Doelter has shown experimentally that that decline in temperature under surface conditions may be from 1240° C.

* Die Eruptivgest. des Kristianiagebietes, iii, 336 (1898).

to 1150° C. for granite, from 1070° to 1010° C. for phonolite, and from 1060° to 992° C. for basalt.* It is clear from Barus's researches that similar differences would be expected under plutonic conditions of pressure. Without dwelling on the older experiments proving that the presence of water and "mineralizers" aids in giving a magma mobility, the more recent one by Barus may be noted.† He has been able to fuse glass at 200° C. in the presence of water! Finally, Oetling found that, when a magma is once molten, the pressure of 200 or 300 atms. tends to keep it molten longer than under normal pressure.‡ Amagat, before him, came to the view that, provided the pressure be high enough, solidification may be indefinitely held back.§ However this may be, experiment fully substantiates the conclusion enforced by field evidences, that plutonic magmas are highly fluid during active intrusion.‖

Enclosures of foreign rocks in the endomorphic zones of intrusives.—To return to the original problem of the country rock inclusions actually seen in the field at internal intrusive contacts. We have found grounds for believing that such blocks could not, in the vast majority of occurrences, have remained in their present positions close beside the niches in the wall or roof whence they came, unless the magma enclosing them were very viscous at the time they were rifted off. Additional testimony to this mechanical indication of high viscosity is derivable from the normal chemical inactivity of the magma in contact belts of the kind. The blocks, as a rule, show few absorption phenomena or none at all, and are but rarely accompanied by diffusion aureoles. The boundaries of the fragments against the igneous rock are more often than not exceedingly sharp, like the new molar-contact surface formed by the rifting away of the same blocks. Lastly, the contact-metamorphic changes wrought in the blocks are often no greater than those effected in the country rock many yards from the molar contact. Viscosity of about the same degree will explain the suspension of the basic segregations in granites, syenites, etc., and probably approaches that of the Archæan granitic magmas which, according to Lawson, were capable, under enormous dynamic stresses, of shearing and attenuating foreign blocks suspended in those magmas near the moment of consolidation of the latter. Lawson has also suggested that, although the viscosity was so great, the temperatures may have been high enough to melt up the more basic fragments com-

* Tscher. Min. u. Petrog. Mitth., xx, 232 (1901).

† This Journal, vi, 270 (1898).

‡ Tscher. Min. u. Petrog. Mitth., xvii, 332 (1897).

§ Comptes Rendus, No. 16 (1893).

‖ Cf. Iddings, Jour. Geol., i. 833 (1893); A. Geikie, Ancient Volcanoes of Great Britain. ii, pp. 413–22–39 (1897).

pletely.* Whether solid or molten when sheared or pulled out, such blocks could not sink in the magmas because of their thick-pasty condition.

Overhead stoping in magmas of high fluidity.—If then, a visible contact zone shows that its magma could, in the enfeebled condition just prior to solidification, rift off blocks in great number from the invaded formation, it is clear that the same magma could carry on the destructive work much more rapidly when highly fluid. Not only would the many, often intersecting, apophyses more readily force their way into the country rock; the certainty of loss to the walls and roof would be increased because of direct gravitative pull. Blocks having insufficient attachment to the roof because of joints or other planes of weakness in the superstructure, would sink in the magma less dense than themselves.

Another cause of the mechanical destruction of the vault, a cause, perhaps much more important than the two cited, may be found in the special conditions of strain existing at molar contacts. The temperature of the invaded rock is raised by the adjacent magma many hundred degrees Centigrade above the temperature the rock may be assumed to have had before the intrusion began. As much as two per cent of volumetric increase could thus be produced in the solid rock close to the magma. Farther away, though still near the contact, the elevation of temperature and corresponding expansion in the country-rock would be of a much lower order. It is evident that enormous strains would be set up in the relatively thin shell of the vault bounded by the molar contact. The strains would be comparable to those observed in surface cliffs and quarries exposed to rapid but small changes of temperature, but on a much greater scale. The complex stresses induced might conceivably result in the extensive shattering and exfoliation of the country-rock.†

In the operation of all these various causes, it is highly probable that, during most of its history, a molten plutonic magma has a much greater power of rifting masses from its walls and roof than in the short closing stage of its career as such before crystallization is completed.

The opening of the magma chamber.—By the integration of relatively small effects in stoping, the chamber or space opened for the continued intrusion of a magma may be indefinitely enlarged, so long as heat and thickness of crust sufficient are supplied by the conditions of nature. Its form would be that of a downwardly enlarging compartment within the invaded formation, though a pipe-like chamber could also

* Ann. Rep. Geol. and Nat. Hist. Surv., Canada, 1887, Pt. F, pp. 131–2–3–8, etc.

† Cf. Reade's experiments, op. cit. pp. 17–28.

be produced. The time required for the formation of a chamber appropriate to a "batholith" or large stock may be great, but doubtless no greater than that posited, for example, by Brögger in the fashioning of the huge laccolithic chambers of the Christiania Region,* and certainly no greater than the time demanded for the opening of a similarly extensive chamber by mere caustic action on the molar contact. Stoping will vary in rapidity with the size of the blocks rifted. The average block from visible contacts is most probably smaller than the average block rifted during the much longer period of high fluidity in the magma. Perhaps the partially sunken blocks resting on the quartz porphyry "laccolith" near Drammen, Norway, may represent possible sizes for such blocks. They are long slabs from 250 to 1500 meters in diameter.†

A brief statement of this central idea of the stoping hypothesis has been given by Lawson in a review of certain of Brögger's writings. So far as known to the present writer, this noteworthy paragraph contains the only clear enunciation of the doctrine to be found in geological literature, and is worthy of quotation in full:

"The essential features of the assimilation hypothesis were formulated by the reviewer some years ago, before the publication of Michel Lévy's views, and urged as a satisfactory explanation of the remarkable relations which obtain between the Laurentian granites and gneisses and the upper Archæan or Ontarian metamorphic rocks. These intrusive granites and gneisses occupy vast tracts of the Archæan plateau and there seems to be no escape from the view that they bear a batholitic relation to the crust which they invaded from below. Portions of the crust were absorbed, but there are two possibilities as to the method of absorption, viz: 1. by fusion; 2. by sinking into the magma. The numerous blocks of rocks scattered through the granites lends much probability to the latter having played a part in the process. Such batholites were doubtless accompanied by laccolitic satellites."‡

It is recognized that the stoping hypothesis, like the older ones which demand the supposition of high magmatic fluidity, must meet a difficulty suggested by the last consideration. If the eruptive body was, throughout its whole history, plutonic, as is generally assumed for the world's great granite massifs, how could the roof of its chamber, when of large span, be supported? The question is of great importance, but the intended limits of this paper will not permit of its being fully dealt with, even if all the elements of the problem were at hand.

* Die Eruptivgest. des Kristianiagebietes, ii, 144 (1895).
† Brögger, op. cit., p. 136.
‡ Science, New Series, vol. iii (1896), p. 637.

The depth of the pressure-solid basement supposed to form the foundation of such magmas, the density stratification of the liquid magmas themselves, the distribution of diluting "mineralizers," the efficiency of buttresses left in the act of stoping, the possibility of progressive lateral cooling in stock or "batholith," the strength and thickness of the chamber vault, are among those elements.

The difficulty of reconciling the idea of stoping as a process extensively operative in intrusion, with the apparent necessity of postulating flotation for the crust overlying still liquid batholiths, is partly met by recognizing the influence of compression in the magmas under their heavy crustal loads. The full significance of such compression cannot, for lack of existing experimental data, be told, but, from the known analogous compressibility of glass, it is probable that the quantitative value of the compression in great depths is considerable. As we have seen, this conclusion is in no sense inimical to the possibility of stoping, since rifted blocks are under the same pressure as the magmas enclosing them.

Further, it has been seen from a discussion of Table IV, that many solid crystalline schists and sediments (staple rocks in the earth's crust) might be expected to float on the heavier gabbros when the latter are highly fluid. Reasons are given below for the conclusion that earth-magmas are, in general, arranged according to the scheme of density stratification, and that, beneath the less dense, acid magmas, as well as underlying the solid crust, there is a world-circling layer of potentially molten gabbro magma. If this view be accepted, it is possible to credit some roof-support for a large batholith to the immersion in gabbro of the bases of the walls and of large intervening pillars of solid roof-rock invaded by the batholith. The required strength of the whole roof becomes, on that supposition, of comparatively low degree, equivalent, namely, to that of the relatively small vaults between the main walls and pillars; such vaults as belong to the associated stocks so commonly believed by geologists to represent the upper portions of huge, regional batholiths. Provided that the roofs of the stocks remain intact, their chambers, filled with magma less dense than the overlying crust, will represent so many floats for the roof of the whole batholith.

Needless to say, the body of desired facts ascertained in field observations is insufficient to permit of an adequate test of these hypothetical postulates. The problem is, therefore, at present, largely indeterminate. It might, perhaps, be adequately treated by actual analytical study of type occurrences where the phenomena of nature indicate either that wholesale foundering has not taken place, or, on the other

hand, that partial subsidence of graben-blocks at fault-troughs can be proved. The former conclusion seems warranted for the very numerous smaller stocks, and the writer believes that it is in the main permissible, and even necessary, in the case of most batholithic masses.

Tests of the Hypothesis of Overhead Stoping.

The hypothesis of magmatic overhead stoping is believed, then, to be founded on a thoroughly competent geological process, one for which there is a certain amount of clear ocular demonstration in the field, namely, contact phenomena much more widely disseminated in nature than the dislocation or caustic phenomena yet proved on behalf, respectively, of the "laccolithic" and "marginal assimilation" theories. It is believed that neither of the latter theories lays enough emphasis on the normal property of internal plutonic contact belts of systematically containing large numbers of fragments from the invaded formations. The laccolithic theory suffers further from the absence of observations proving the existence of basements of country rocks for the larger granite massifs. The hypothesis of stoping and rapid sinking explains the general lack of such blocks in the central portions of the massifs, and is corroborated by the facts, going to show that, precisely under those conditions when blocks would *not* sink in the less dense magma, the latter exhibits independent evidence of being enormously weakened in its thermal, chemical, and physical (rifting and stoping) activity.

how about straight forceful injection?

Testimony of laccoliths.—In view of the extreme improbability that one can often, if ever, expect to find the pressure-solid, or otherwise determined floor of a deep-seated magma basin,* it is of interest to question the few known laccoliths with visible floors for information as to the efficiency of stoping. Of course, the conditions for rifting and for the submergence of blocks from the roof, are much less favorable in the rapidly intruded magma of a typical laccolith from what they would be in a deeper-seated magma in direct communication with the "ewige Teufe." Some notable degree of viscosity seems necessarily assumed as characteristic of laccolith magmas. The *proved* laccoliths are all small and are surrounded on every side, except at the narrow conduit, by cold rocks, so that chilling must be much more rapid than under plutonic conditions. Nevertheless, the attempt has been made to find, in the published descriptions of type laccoliths, any statement for or against the probability of a limited amount of rifting and stoping. In such small igneous bodies, it would be

* Brögger, op. cit., p. 134.

unlikely that total digestion would destroy blocks fallen from the roof. They might, therefore, be looked for on the floors. So far, the writer has discovered no evidence on the point in any of the monographs. The reasons are not far to seek. Very few floors of laccoliths are actually exposed. It is probable, too, that in many instances an observer would have difficulty in distinguishing blocks torn out of the floor from those sunk thither from the roof. Gilbert,* Jaggar,† and others describe fragments at levels above the floor, but do not directly raise the question as to how they were held suspended within the magma. In the laccoliths of the Henry Mountains, the unusually low densities of the invaded sandstones and shales are such as to warrant the belief that fragments of these rocks really floated in the magma. The specific gravity of the Mt. Hillers trachyte, for example, is at 20° C., 2·63. Using Delesse's ratio of 4 per cent of net volumetric increase in the passing of trachyte from rock to glass at the same temperature, and then applying Barus's fusion curve, it follows that the trachyte magma would have, at 1400° C. and one atmosphere of pressure, a specific gravity of 2·34. From Reade's expansion coefficient for sandstone we can calculate the specific gravity of the unaltered invaded sandstone at 1400° C., while conceived as still solid and obeying the normal law of thermal expansion for sandstone. The decline in specific gravity is from 2·15 to 2·06. The corresponding decline for the contact metamorphosed sandstone is from 2·48 to 2·38. The values show a high probability that the average sandstone fragment would float in the magma at least until it was altered nearly to the maximum observed near Mt. Hillers. This conclusion raises the suggestion whether density may not control the formation of some laccoliths in a manner somewhat different from that hypothecated by Gilbert‡—a subject evidently remote from the purpose of these pages.

Jaggar has described large blocks of Cambrian strata as immersed in the laccolithic porphyries of the Black Hills and explains them as due to "excessive doming." Yet it is conceivable that they may owe their present positions to high magmatic viscosity, the magma freezing as they were in the act of slowly floating upwards from the floor or sinking from the roof of the laccolith.

So far, then, laccoliths have given only negative evidence in the test of the stoping hypothesis for plutonic magmas, and, perhaps in the nature of the case, they can never be of great value in determining the truth of the hypothesis.

* Op. cit., p. 66.

† The Laccoliths of the Black Hills, U. S. Geol. Survey, 21st Ann. Rep., Part III, 211 (1901).

‡ Op. cit., p. 75.

Abyssal assimilation.—Other tests of the hypothesis in addition to those of direct laboratory experiment and field observation, are obviously suggested when we leave the igneous contact and consider the fate of the submerged blocks.

Assuming that overhead stoping is competent to form in the earth's crust chambers of the size represented in stocks and "batholiths," the inquiry leads perforce into the problem of magma genesis. If so much mechanical loss has been suffered by the formations invaded by a given magma, what effect will be wrought on the composition of that magma by the submergence of the corresponding fragmentary material? How far will such blocks sink? What is their future history? If it can be shown that the foreign material is to a magma what food is to an animal, does it follow that there will be the equivalent of digestion and, by diffusion, still more intimate assimilation of the country-rocks by the magma? At this point, we must enter the region of theory on the origin of all igneous magmas, a region certainly beset with great impediments to progress. Only so far as these general considerations seem to call for immediate treatment as a further test of our hypothesis, and then but in skeleton outline, does it seem advisable to follow out the subject at this time. It is felt that no other special apology is needed for thus venturing into what must always remain speculation to so large an extent, for *any* theory of intrusion must be similarly correlated with the chemical and physical characters of igneous rocks.

As experiment has thrown much light on the mechanics of intrusion, it may also help deductive reasoning in determining the probable future of submerged blocks. Whether any block would be permitted to sink thousands of feet or several miles from its former niche in the vault, it is probably impossible to say. The locus of denser, though still liquid, layers of magma in which the block would float, cannot be foretold. The block might even sink to the deep level of pressure-solid magma, if it be not already digested on its downward journey. In either case it must undergo an increase of pressure and, with the greatest probability, an increase of temperature.

The added pressure would have, according to the experiments and field studies of Barus, Doelter, Daubrée, Fouqué, Michel Lévy and others, the secondary effect of increasing the capacity of the magma in retaining water and other solvents, even at very high temperatures.* So important are other experiments in this connection that a brief résumé of certain results accruing from them must be given.

* Among the more recent papers, cf.: C. Barus, this Journal, xxxviii, 408, (1889) and xli, 110 (1891). C. Doelter, Centralbl. f. Min., etc., 1902, p. 550; and Tscher. Min. u. Petrog. Mitth., xxi, 218 (1902).

The solubility of rock-forming minerals in silicate magmas has been shown by fusion experiments to depend on *a*, the temperature of the magma; *b*, the chemical composition and fluidity of the magma; *c*, the fusibility of the minerals; and, *d*, on pressure. Doelter has been able to prove that, under one atmosphere of pressure, all the common types of rock-forming minerals are completely soluble in certain representative magmas at temperatures only slightly above those of their respective consolidation points. These magmas were made from granite, obsidian, common basalt, limburgite, phonolite, foyaite, leucite basalt, leucitite, hornblende andesite, and nepheline basalt—a magmatic range so wide as to demonstrate the practical certainty that all silicate magmas have similar solvent properties. He further shows that the melting point of a silicate rock occurs at about the average temperature of fusibility of its constituent minerals. Long before, Bischof easily dissolved clay-slate in fluid lava, using a bellows furnace for fusion.* These important deductions from laboratory investigations correspond to the facts of outdoor nature. Well-known practical examples may be found in the fused and greatly corroded granite inclusions in the basalts of the Auvergne; and, again, in the complete disappearance, by fusion, of the "floating islands" in the caldera of Kilauea.† The high fluidity of the normal plutonic magma would likewise facilitate the complete solution of foreign fragments, as experimentally proved by Doelter.

It is true that the direct influence of pressure tends to elevate the melting points of silicate mixtures, though probably not in a degree proportional to the amount of the pressure.‡ Yet that effect on the solvent power of the magma may be much more than counterbalanced by the indirect effect of pressure in retaining water and other solvents. Once molten, pressure tends to keep silicate magmas molten, since it lowers the temperature point of consolidation.§ In determining the solvent power of a plutonic magma, temperature furnishes here, as in fixing the melting-point, the "coarse adjustment," as pressure furnishes, of itself, the "fine adjustment."

In conclusion, then, it seems legitimate to regard the conditions of the abyssal portions of plutonic magmas as conspiring toward the perfect digestion of a submerged foreign rock fragment during all the time of intrusion except during the short period preceding final consolidation. Even so uncompromising an opponent of the theory of contact digestion by stock magmas as Brögger admits that such assimilation can be, in

* Chem. u. Phys. Geol., Supplement, p. 98 (1871).
† J. D. Dana, Characteristics of Volcanoes, p, 176, New York, 1891.
‡ Doelter, Tscher. Min. u. Petrog. Mitth., xxi, 221 (1902).
§ Oetling, op. cit., p. 370.

the greater depths, exceedingly important, "ausserordentlich bedeutend."* Several cases have been described in which even marginal assimilation at great depths has affected batholithic magmas, though, as we have already seen, such cases are exceptional.

Since it is probable that magmas are more or less completely saturated solutions,† there would doubtless be a volumetric increase on the fusion of each block at whatever depth it attained, an increase comparable to that demonstrated in fusion experiments at 1 atm. of pressure. The question at once arises as to what compensation can be made for the increased bulk of rock-matter below the earth's surface incident to abyssal assimilation on a large scale. Two possibilities suggest themselves in the face of the hydrostatic problem involved. Either volcanic outflow elsewhere, or secular upheaval in the region, would satisfy the conditions. The latter would seem to be more likely of fulfillment in regard to stocks and batholithic intrusions generally. It is to be noted that magmatic stoping would tend to weaken the earth's crust immediately above the intruding body, and there secular elevation of the surface would be particularly looked for. There may, in this way, be found one cause of the huge buckles filled with the "central granites" of alpine mountain chains. This implies that the doming of the great intrusive masses of the Christiania Region, attributed by Brögger to laccolithic injection, may, in reality, be due to this crustal weakening and buckling by magmas working up from the "ewige Teufe." But, at present, it must remain only the suggestion of a possibility, as the writer has no personal knowledge of the region.

It is, moreover, worthy of inquiry whether this sort of live energy of intruding granitic magma may be responsible for many of the well-known cases where the secondary structure-planes in the invaded formations wrap around their respective intrusive bodies. Examples are seen in the highly developed peripheral cleavage and schistosity parallel to the outlines of such magmas in the Rainy Lake region,‡ in the Black Hills,§ and in the Sierra Nevada.‖ Such structures would certainly be produced by the force of magmatic expansion, provided that force be sufficient in amount, for it must be exerted always normal to the chamber-walls.

* Op. cit., iii, 350 (1898).

† Lagorio, Tscher. Min. u. Petrog. Mitth., viii, 504 (1887). Cf. Delesse, Bull. Soc. Géol. France (2), iv, 1393 (1847).

‡ Lawson, Ann. Rep. Geol. and Nat. Hist. Survey, Canada, 1887, Pt. F, map.

§ Van Hise, 16th Ann. Rep. U. S. Geol. Survey, Part I, 1894–5, pp. 637 and 815.

‖ Turner, 17th Ann. Report U. S. Geol. Survey, Pt. I, 1895–6, p. 555.

Formation of compound magmas by abyssal assimilation.—To return to the main line of argument. If abyssal assimilation by a magma be a fact, that magma must become more and more mixed with the products of assimilation. Any eruptions during, and subsequent to, the mixing might be expected to show indications of the gradual alterations of the magma in the normal case where magma and invaded formations have different chemical composition. The writer believes that the sequence of eruptive-rock types derived from such a heterogeneous magma would not be directed simply by the assimilated product, but would follow definite physical and chemical laws which govern heterogeneous magmas however formed. These laws are embodied in the modern principle of differentiation. By differentiation, the irregularly constituted and compound magma of assimilation becomes definitely split up into submagmas which may, on eruption, represent actual igneous rocks visible at the earth's surface.

Differentiation of compound magmas.—Numerous recent discussions and summaries of the well established facts on which the doctrine of differentiation is based, render unnecessary in this paper a restatement of the evidence. No other principle has yet been evolved which explains so satisfactorily the phenomena of consanguinity; the fact of type-constancy, in the midst of variety, among the eruptive rocks of the world; the normal order of eruption; the phenomena of complementary dikes; the border facies of many stocks; and the existence of basic and acid segregations. Michel Lévy himself, so long a powerful and adverse critic of the differentiation theory, has of late been won over to a recognition of its value in explanation.*

The consequences of our hypothesis demand that some emphasis be laid on the probable nature of the differentiating process involved in the splitting up of the abyssal magma. Without wishing to be understood as denying the probability of several other causes for differentiation, the writer will note those conditions which, in his opinion, favor one cause in this particular instance rather than any other.

Each year new facts are accumulated, going to prove the existence, at no great depth below the earth's surface, of a general ferromagnesian magma, and recent theories of the igneous rocks have thus returned in one point to the older views of Bunsen and others. As yet it cannot be affirmed that this or any other subcrustal magma is normally solid by reason of pressure and only locally fluid by the local release of the pressure. Nor can it be certain that a rock fragment, stoped out from the vault of an intrusive body, would sink necessarily

* Bull. Soc. Géol. France (3), xxv, 326 (1897).

to a magma layer as dense as itself. Yet it appears not to stretch the probabilities too far, to assume that pressure solidity would not characterize, in general, the lower basic part of a magma basin above the level where a normal siliceous sediment or schist block would come to rest. As a rule, that would mean that the magma must become acidified by the assimilation of the more siliceous rock. The equilibrium would thus be disturbed and an upward current of the locally modified magma would be set up. Such action would be specially notable in the case of gabbro and peridotite magmas intruded into any staple member of the fundamental crystalline schist complex. Downwardly-directed currents in the magma would also be developed during the sinking of the blocks.

Such currents would tend toward the rapid formation of horizontal homogeneity at the various levels in the chamber, and of vertical heterogeneity (on a larger scale than the similar heterogeneity expected by the older assimilation theory), governed by the law of increasing density with depth. The more acid layers would concentrate at the top, the more basic remain at the bottom, of the magma basin. The layers would, it is believed, be more or less definitely composed by the laws of differentiation operating by diffusion. It is certain that diffusion is aided by agitation,* and in the density currents and those induced by the falling blocks we have two efficient causes for agitation. Further, Braun and Alexejew have shown that enhanced pressure stimulates the differentiation of a complex magma into distinct fluids.† Increased pressure is, as we have seen, felt in the magma by the conversion of each fallen block into liquid rock. Finally, certain other facts of recent discovery seem to bear out the conclusion that differentiation by the gravitative effect actually occurs. Morozewicz cites instances of the process in his fusion experiments and in the study of glass furnaces.‡ Doelter has stated that such results adhere to special cases both in his own experiments and in those of the Russian investigator; yet their significance is still great, since they agree with Gouy and Chaperon's theoretically deduced principle of gravitative stratification in saline solutions,§ as well with some positive field observations. For example, Sir A. Geikie describes the separation of a lower layer of picrite and an overlying layer of olivine basalt in the same lava-flow, and finds it probable that similar differentiation has taken place in basic sills.‖ Becker's physical researches¶ and Rosenbusch's conclusion from more purely petrological consid-

* Becker, this Journal, iii, 25 (1897). † See Becker, op. cit., p. 32.
‡ Tscher. Min. u. Petrog. Mitth., xviii, 170, 233 (1898).
§ Ann. de chimie et de physique, ser. vi, vol. xii, 1887, p. 384.
‖ Ancient Volcanoes of Great Britain, London, 1897, vol. i, pp. 419 and 442, and vol. ii, p. 310. ¶ Op. cit., p. 37.

erations* are accordant with the hypothesis. An interesting statement of it is given by Walker.† In view of the agitation produced by the powerful currents set up under the special conditions inferred by the stoping and sinking of blocks, it is also probable that gravitation would be capable of stratifying the material directly dissolved by a magma from the walls of its chamber. Secondary and less important causes may explain the existence of complementary dikes, basic borders and segregations.

The eruptive sequence.—The particular kind of igneous rock erupted from the magma basin will evidently depend on the level from which the magma is drawn. In general, surface, hypabyssal, and even plutonic bodies may be expected to originate in the upper portions of the basins. If the original magma be more acid than the invaded formation, the former would probably, in its upper part, be modified by abyssal assimilation in but subordinate degree, and the sequence of the eruptions would normally be from acid to basic. If, on the other hand, the original magma be more basic than the invaded formation, that magma would be specially altered in the upper part of the basin and a long continued series of eruptions would show the order of basic to acid. Two different petrogenic cycles are thus possible. By thorough solidification of the upper layers of the magma (accompanied by secular denudation at the earth's surface), and renewed eruptivity, the petrogenic cycle for an area might be repeated as a whole or in part.

In deciding as to which of the two cycles should, by our hypothesis, be most commonly represented in nature, it is clear that each eruptive field and petrographic province should be studied by itself and the results correlated for the world. The impossibility of such complete correlation at the present time need not discourage the attempt to test our hypothesis by such generalizations as may now be made. Can we arrive at a decision as to what is the average invaded formation and what the average primary magma of the earth?

The first question may be answered with a high degree of probability for about one-third of the earth's surface, namely, the continents and the immediately adjoining belts of the sea-floor. In those areas, the greatest volume of rock above the average isogeotherm of rock-fusion is doubtless made up of the acid crystalline schists. The composition of the suboceanic crust generally is almost entirely a matter of speculation. The second question is beginning to assume a most prominent place in petrogenic theories. On the continents, the staple plutonic rock is the acid granite; the staple volcanic eruptive,

* Mikros. Physiographie, etc., ii, 552 (1896).
† This Journal, vi, 410 (1898); cf. Vogt. Zeit. für prak. Geol., 1893, p. 279.

basalt. On the oceanic areas, the staple visible eruptive is the basic, and necessarily volcanic, basalt or allied augite andesite. These facts of relative volume in igneous output agree with the views derived from chemical considerations long ago by Bunsen,* and more recently by Michel Lévy† and others. Two fundamental magmatic types, the alkaline granitic and the ferromagnesian, dominate among the world's igneous rock-types. The fact that they do exist is independent of theory. Certain other facts point to the conclusion that the supply of the ferromagnesian magma available for eruptive purposes is much greater than that of the alkaline magma.

In those conduits where the escape of igneous magmas from the earth's interior to the surface takes place to such an extent as to build large volcanoes, we should expect the sequence of eruption to be completed by effusions of lava more nearly representing the original or primary magma than the antecedent flows. The reasons for this are: first, that assimilation in the immediate vicinity of the vent would, in that late stage in the development of the volcano, have progressed so far as to have enlarged the conduit to a size suitable to a large cone; secondly, that the vent would, by the long continuance of the volcano's activity, have become freed from the products of the assimilation; and, thirdly, that the latest flows would be derived from the original magma practically unaffected by assimilation. Now, it is a significant fact that the latest extrusive product of the great majority of the largest volcanoes, such as Etna, Fusiyama, Chimborazo, Cotopaxi, Kilima-Njaro, etc., is, so far as known, either basalt or augite andesite.

Not less important is the equally indisputable fact that the greater fissure-eruptions of the globe give birth to only one kind of lava, again basaltic. The familiar examples in Iceland, northwestern Europe, India, the northwestern United States of America, and the Hawaiian archipelago, tell no uncertain story concerning the nature of the vast reservoirs from which they have derived their enormous volumes of lava. The more acid flows which occur in any of these regions are insignificant in bulk compared with the total basic output. The question is quite open whether the former are not the product of differentiation acting on the primary basaltic magma influenced by the assimilation of the continental rocks, which are characteristically more acid. Further, we should expect assimilation to be less active in determining the composition of fissure eruptives than in preparing the secondary magmas erupted in volcanic cones or injected in intrusive forms. From the nature of the geological dynamics rendering possible the rapid expulsion of

* Pogg. Annalen, lxxxiii, 197. † Op. cit., p. 368.

the voluminous flows at master fissures, it is clear that the corresponding magmas had relatively easy access to the surface and had not to work their own way through the earth's crust. The plateau lavas therefore merit particular notice in the search for the general earth-magma or magmas. It is doubtful that enough emphasis has been placed on the volume, relative abundance and mode of geological occurrence characterizing the different eruptive types, in the published discussions on the origin of igneous rocks. Those elements must always be of prime importance in the solution of the problem of assimilation.

For different reasons excepting that derived from the enormously greater abundance of basaltic lavas on the earth, Dutton came to this same conclusion as to the nature of the "primordial matter." He has rightly dwelt on the fact that basalt is a "synthetic or comprehensive type of rock." His theory of the derivation of other igneous rocks by simple fusion of sedimentary formations derived in their turn, by weathering, from the "primordial matter," takes insufficient account of the facts of differentiation learned since 1880. Yet his theory has a suggestive relation to the one proposed in these pages.*

It is not essential to our present purpose to decide on the question whether the acid-alkaline magmas of the continents represent the more or less altered primal material segregated on the original crust of the earth, or are the product of the secular alteration of continental sediments derived from the synthetic basaltic magma—if such decision be really possible. The main facts of igneous rock distribution and the *a priori* conception that alkaline magma must float on the ferromagnesian magma, lend themselves to the belief that a gabbroitic magma underlies the surface of the whole earth at a depth not too great to prevent its energetic eruption. If, during such eruption, overhead stoping and abyssal assimilation accompanied by differentiation, occur, the gabbroitic magma will be modified and a normal world sequence from basic to acid be established. In spite of the numerous exceptions to this order in nature, a fair judgment on the case must reach the conclusion that such a law governs intrusive bodies at least. We have already seen reasons for believing that the order may, on the same hypothesis, be abnormally reversed for plutonic masses, and *should* be reversed for the greater volcanic rock-bodies. Granite, on account of its superior stoping power and low density, compared with the basic plutonic rocks, should be the more common among those irruptives exposed by denudation at the earth's surface.

* Rep. High Plateaus of Utah, p. 125 ff., Washington, 1880.

Summary.

A general summary will be of value in gathering up the various threads of the argument tending to support the hypothesis of magmatic overhead stoping. The fundamental facts of the field and laboratory will be briefly recapitulated. There will follow a résumé of the tests which have so far been applied to the hypothesis. In those tests, it is believed, may be found a material strengthening of faith in the hypothesis, since it is seen that it explains several principal petrological facts not necessarily, or, at least directly, connected with the idea of stoping.

The facts of the field.—1. Many, and perhaps most, stocks, so-called "batholiths," and "central granites" show an almost entire lack of sympathy between the structural planes in the invaded formations and the form of the intrusive body.

2. For some of these bodies there is conclusive evidence that their respective magmatic chambers were not prepared for intrusion by circumferential faulting. For the great majority of the remainder, the indications for such faulting is negative.

3. For many, perhaps most, stocks and "batholiths," the combined contact phenomena demonstrate some kind of active assimilation of their corresponding country rocks by the respective magmas.

4. In the normal stock and "batholith," there are usually: a decided lack of any enrichment of the endomorphic zone by substance dissolved from the invaded formations; a general freedom from foreign inclusions in the interior, together with a characteristic abundance of angular enclosures near the contacts; an exceedingly sharp line of contact with the country rocks; equally sharp contacts of the foreign fragments and their respective hosts; lack of direct sympathy between the composition of the intrusive bodies and their respective country rocks; a general high degree of homogeneity in the composition of the igneous body; the common occurrence of many long and narrow apophyses from the igneous body, indicating strong liquidity at the time of the intrusion of the main igneous mass.

5. Field relations, coupled with a comparison of the chemical and mineralogical characters of igneous rocks the world over, show well established and wide reaching laws of magmatic differentiation.

6. Isolated observations in nature prove that solid rocks may sink in molten lavas because of differential density; others show that fragments of solid rock can be more or less completely dissolved in molten lava.

The facts of experimental research.—The experiments of Barus, Doelter, Daubrée, Delesse, Cossa, Bischof, Oetling, Morozewicz and others show:

1. That representative natural or artificial silicate mixtures at ordinary atmospheric pressure become thinly molten at a temperature only slightly above that of solidification;
2. That, in every instance, a great increase of volume characterizes the change from the solid to the liquid state;
3. That, with strong probability, this volume increment and resulting density decrement are so far preserved in rock magmas under plutonic conditions as to forbid the flotation of blocks of the average country rock immersed in the average magma in depth (other allied conclusions have been already summarized on pages 279 and 280);
4. That the chief rock-forming minerals are soluble in all of the melted silicate mixtures yet investigated, and at the temperatures ruling when those mixtures are thinly molten;
5. That pressure aids the solubility of minerals indirectly by retaining in the magma, water and other solvents, but retards it, probably in much less degree, by raising the temperature of fusion for silicate minerals.
6. That there is evidence of differentiation in molten magmas by gravitative effect.

The tests of the hypothesis of overhead stoping and enlargement of magma chambers.—Reasons are given for concluding that:

1. The cause cited for overhead stoping is quantitatively sufficient for the majority of stocks and "batholiths."
2. The presence of foreign inclusions at internal contact belts of stocks and "batholiths," and the detailed phenomena associated with those inclusions, are facts of nature expected on the hypothesis. It is implied that the removal of blocks from the chamber-vault is comparable to the work of a river. The active corrasion of a stream in its youth is rapid and corresponds to the rapid stoping of an intrusive body in its first long stage of high temperature and fluidity. The feeble corrasive power of a stream in its old age corresponds to the diminished stoping activity of the magma in its viscous, solidifying period. The conclusion is drawn that, under the energetic conditions of high liquidity, a magma may open, in the invaded formation, a chamber of a size appropriate to a stock or "batholith." Independent grounds exist for believing that ample time is allowed by granitic intrusion for such integration of relatively small effects.
3. The corollary of abyssal assimilation has many experimental and other data in its favor and is backed up to a greater

degree by such facts, than the theory recognizing caustic assimilation as occurring merely or chiefly on main vault contacts.

4. The hypothesis is supported by a survey of the facts of magmatic differentiation. It is believed, further, to give the best explanation of the petrogenic cycles yet found illustrated in nature, and to explain with special force the normal eruptive sequence. At the same time, the hypothesis is not weakened by the known cases of the reversal, or other modification, of that order of eruption.

5. The hypothesis accords with the facts known with regard to other kinds of igneous intrusion. Even in the case of those great granitic massifs organically associated with master-lines or zones of dislocation (e. g., the tonalite and the "Judicarienlinie" of the Tyrol), the magma chamber may have been principally opened by overhead stoping. The same process may similarly enlarge the deep-seated cross-section of a volcanic neck. Yet no one can deny its practical insignificance in the intrusion of sheets or dikes, nor, for obvious reasons, does that fact injure the strength of the proposed hypothesis when dealing with much larger igneous bodies. The latter must be longer molten by reason of their size and direct communication by means of convection and other currents with the earth's interior. The same remark made concerning dikes and sheets applies also to the proved laccoliths, although it is probable that, in a very limited way, laccolithic magmas may carry on stoping and therewith assimilation in their hot interiors. Dikes, sheets and laccoliths are but offshoots of the greater magma-basins with which the hypothesis is concerned.

Among the further tests needed comes first, perhaps, that for further experimental investigation of molten rock magmas under high pressures. It should be particularly determined whether the carbon and silicon compounds show analogous behavior under high pressures, as they certainly do at ordinary pressure and at temperatures below, at, and above their respective melting-points. Fusion experiments additional to those of Barus and covering a range of igneous rock types and at varying high pressures, would be still more valuable than the indirect method of comparison between hydrocarbons and silicates.

General Summary on the Mechanics of Intrusion.

In the foregoing pages, the writer has briefly compared the hypothesis of overhead stoping in the formation of magma chambers with the "laccolithic" theory of crustal displacement and with the theory of marginal assimilation of invaded formations. Since the question is intimately connected with that of the origin of the igneous rocks, it might be considered

necessary to compare as well the effect of the rising of the isogeotherms in fusing stratified formations. This paper has already assumed such proportions that that subject may well be left in abeyance. Suffice it only to point out that the igneous rocks of most intrusive bodies are demonstrably exotic and have penetrated considerable distances vertically into their invaded formations which are *not* fused because of the rising of the isogeotherms. The fusion of rocks by this method cannot, therefore, of itself explain the formation of the actual chambers opened to human sight by secular denudation.

One must feel a certain hesitancy in taking a definite position on a matter of such fundamental importance; yet a categorical statement may bring into sharper relief the main conclusions to which the writer has come. Dikes, sheets, laccoliths, "bysmaliths," and perhaps a few of the smaller stock-like, plutonic bodies are conceived to be due to crustal displacement *permitting* intrusion; in the preparation of the greater and much more important subterranean magma chambers, marginal assimilation is believed to be a true cause, but, in the large, to be quite subordinate to magmatic overhead stoping, while bodily crustal displacement is in but indirect control inasmuch as it only localizes the areas where stoping is to form the chambers; and abyssal assimilation of stoped-out blocks, supplemented by the subordinate marginal assimilation, may be held responsible for the preparation or notable modification of magmas, whence come, through differentiation, most of the igneous rocks of the globe. The plateau-basalts would appear to represent the one widely distributed kind of magma not essentially affected by assimilation.

Geological Survey of Canada, Ottawa, Canada.

ART. XXX.—*Brachiosaurus altithorax, the largest known Dinosaur;* by ELMER S. RIGGS.

THE writer some time since called attention* to a partial skeleton of an herbivorous dinosaur of unusual proportions obtained from the Jurassic of western Colorado. On account of the difficulty in distinguishing between a number of genera already referred to the Sauropoda, it did not then appear advisable to further complicate the problem by proposing a new generic name. But as the unique characters of this animal have become more and more evident it now seems desirable to give it a name, even though it ultimately be found to fall within one of the three or four uncertain genera proposed by Marsh and Cope. The term *Brachiosaurus altithorax* is therefore proposed in recognition of the great size and unusually long humerus of this specimen.

The generic characters are: humerus longer than femur; thorax unusually deep; centra of posterior thoracic vertebrae longer than wide; anterior caudal vertebrae amphicoelian and their diapophyses not vertically expanded; coracoid elongate in direction of scapular suture and having glenoid cavity facing antero-externally.

The specimen upon which this genus is based was collected by the Field Columbian Museum paleontological expedition of 1900, from the Grand River valley of western Colorado. Credit for its discovery is due to Mr. H. W. Menke of this Museum. The specimen consists of the humerus, coracoid, femur and ilium, all from the right side; the sacrum, seven thoracic and two caudal vertebrae, together with a number of ribs and other bones. The parts were, with the exception of the ribs, preserved in their relative positions, and as the specimen was isolated there can be no question that all belonged to one individual.

The distal end of the humerus was exposed, broken and displaced as surface fragments. Associated with its proximal end was the fairly well-preserved coracoid. Some fifteen feet farther along the hillside the sacrum and pelvic bones appeared lying with spines downward. Two partially weathered caudals were closely connected with the posterior end of the sacrum. The thoracic vertebrae stretched forward in an unbroken series with the ribs scattered on either side and more or less displaced. Up to this point there seemed every reason to hope that the whole anterior portion of the skeleton would be found. But at the end of the seventh presacral vertebra the thin clay

* Science, April 5, 1901.

stratum in which the bones were imbedded "pinched out" and was replaced by a thickening of the massive ledge of sandstone which overlaid it. The presence of pebbles at the base of this sandstone, as well as the uniform direction in which the ribs were displaced, showed that the anterior portion of the skeleton had been carried away by the action of a water-current before it had become thoroughly imbedded.

When the surface fragments of the humerus had been carefully collected and fitted to the portion still in position, that bone stretched out to such an unheard-of length that the writer was for the time convinced that it must be a crushed femur. This conclusion was given additional weight by finding, soon after, a well preserved femur of almost identical length. However, when removed from the matrix in the laboratory and the two compared, all doubt was removed by the characteristic form of the head of the humerus as well as the presence of a well defined deltoid crest.

The length of the humerus and femur, together with the immense size of the thorax, at once establishes the fact that this is the largest and longest-limbed of all known land animals, as well as the only dinosaur known to science in which the humerus is longer than the femur. Assuming that the lower fore-leg bones were proportionately long, we have to do with a creature whose shoulders were carried far above his hips and whose fore-legs played a more important part than the hind ones. Such proportions at once suggest arboreal food-habits. Instead of rearing upon the hind legs and supporting itself by means of a ponderous tail, as were the evident habits of *Brontosaurus* and *Diplodocus*, this animal may from sheer length of limb have been able to browse at will upon the foliage of tree and shrub. What were the proportions of the neck can only be conjectured; to be consistent with the proportions of body and limbs it must have been long and flexible. The short spines and the slight processes of the anterior caudals show that the tail was much reduced both in size and in length. This then was the giraffe among dinosaurs, just as *Claosaurus* was the kangaroo.

Description of Skeleton.

The humerus is somewhat crushed antero-posteriorly and twisted so that the head and distal end are brought into the same plane (fig. 1). The surface of the distal end has flaked away in the process of weathering to a firm chalcedony core. In proportions the humerus approaches more nearly to that of *Diplodocus* than to any other well-known American genus. The head is considerably expanded, forming a rounded prominence

especially conspicuous in its posterior aspect (fig. 2). The great tuberosity is stout and rugose; its proximal surface meets the lateral margin of the shaft in a pronounced angle. This angle is not produced posteriorly to enclose a fossa as in *Morosaurus*. The mesial border below the head is drawn out into a rather thin margin, but roughened for muscular attachment. The deltoid crest is partially broken away, but was evidently prominent. Its base forms, with the anterior surface of the shaft, a broad and shallow concavity. Midway between the deltoid crest and the great tuberosity is a second rugose surface evidently for insertion of other shoulder muscles. The epicondylar ridge is entirely lost owing to the weathering to which the distal end has been subjected. The direction of the bone fiber on the lateral margin indicates that it was quite prominent. All traces of rugosity have likewise disappeared from the articular end, indicating that the humerus was probably some inches longer than it now appears.

The coracoid is a less massive bone than that of *Brontosaurus* (fig. 3). It is elongate antero-posteriorly, rounded below and straight at the coraco-scapular suture. The glenoid articular surface is directed outward as well as forward, a feature noted in no other Sauropod genus. The antero-inferior surface is thick and rugose near the glenoid cavity, from which it is separated by a narrow notch only. The inferior border becomes gradually thinner and its rugose character disappears midway between the glenoid cavity and the anterior scapular border. The marginal concavity noticeable in the specimen at this point is partially due to crushing from contact with the head of the humerus while in the matrix.

The femur is well preserved though somewhat compressed antero-posteriorly (fig. 4). Regardless of its great length this bone is quite as stout in the shaft as that of *Brontosaurus*, though the articular ends are proportionately less expanded. The lateral surface of the shaft has a prominent convexity one-fourth of its length below the great trochanter. A marked rugosity, possibly for the insertion of one of the gluteal muscles, extends downward from the great trochanter to this point. The fourth trochanter* forms a rugose prominence on the posterior margin of the shaft, as in all of the Sauropoda.

The presacral vertebrae are of the pronounced opisthocoelian type. They are distinguishable from other Sauropod genera by the unusual length of their centra. This, in the first presacral, is slightly greater than the breadth; it gradually increases in the succeeding members of the series until at the seventh it exceeds the breadth by one-fourth. The centra

* Dollo, Bull. d. Mus. d. Hist. Nat. d. Belgique, Mars, 1883. Osborn, Memoirs of Am. Mus. of Nat. Hist., Part V.

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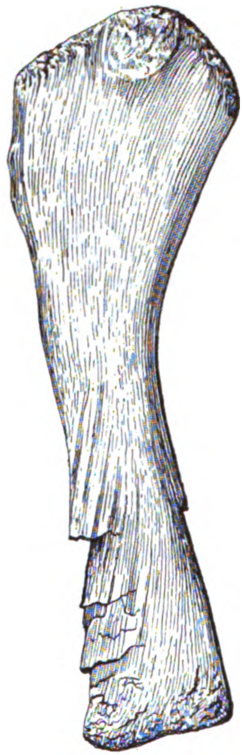

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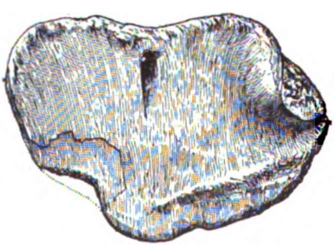

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BRACHIOSAURUS ALTITHORAX.

Fig. 1. Posterior view of right humerus.
Fig. 2. Proximal end of same.
Fig. 3. Lateral view of coracoid.
Fig. 4. Anterior view of right femur.
Fig. 5. Proximal end of same.
Fig. 6. Posterior view of proximal end of a thoracic rib.
Fig. 7. Distal end of femur.

are deeply hollowed by lateral cavities. The whole character of their sculpturing tends toward a lightness bordering upon fragility. In this particular they are approached most nearly by the vertebrae of *Diplodocus.*

The sacrum is composed of four firmly coalesced vertebrae. Its most distinctive feature is its great breadth in comparison with its length. The measurement across the anterior end of the transverse processes is one-fourth greater than that of the posterior end and one-third greater than the type specimen of *Brontosaurus.* The first sacral rib arises from the anterior end of the centrum and is relatively unimportant. The second arises from the whole length of the centrum and is by far the strongest of the series. Its iliac articular surface is much expanded and marks the axial point in the sacrum. The third and fourth sacral ribs arise from the anterior half of their respective centra. As neither the sacral nor presacral vertebrae have yet been removed from the matrix, the description of their spinal elements will be deferred until a future publication.

The anterior caudal vertebrae are amphicoelian in form and relatively small in comparison with those of other Sauropoda. The anterior faces of the centra are more deeply concave than the posterior faces. Since the vertebrae were found lying upon their sides in close apposition with the sacrum, the marked posterior concavity can hardly be attributed to distortion. Unfortunately the spine in caudal I is not preserved. In caudal II the neural arch is as simple as in caudal VIII* of *Brontosaurus* and the spine is scarcely as long. There is no trace of lateral cavities in the centra, or of the broad vertical plates developed from the diapophyses in that genus. On the contrary, these lateral processes are simple, peg-like prominences slightly flattened vertically. The zygapophyses are imperfectly preserved in this specimen, but were apparently slight. The neural spine is short, stout, laterally compressed at the middle but expanded into a rugose knob at its extremity.

The unusual length of the ribs bears evidence of the immense thorax of this animal. In the mid-thoracic region they measure fully nine feet ($2{\cdot}745^{m}$) in length. The capitulum and tuberculum are almost equally developed and widely separated, to give the firm anchorage necessary to the great length of the ribs (fig. 5). In some instances the attachment is strengthened by a second tubercle on the posterior surface of the head similar to that figured by Marsh† in the cervical ribs of *Apatosaurus.* The anterior surface of the shaft below the head is perforated

* Caudal VII according to Marsh's restoration.
† The Dinosaurs of North America, p. 167.

by a large foramen which leads to an internal cavity in the shaft.

Measurements.

	M.
Humerus, length parallel to axis	2·04
" greatest breadth of proximal end	·65
" thickness of head antero-posteriorly	·28
" least breadth of middle of shaft	·24
" distance from angle of great tuberosity to upper margin of deltoid crest	·51
" length of deltoid crest	·24
Femur, length parallel to axis	2·03
" breadth of head and great trochanter	·59
" breadth at fourth trochanter	·43
" breadth at distal end	·58
" distance from head to upper margin of fourth trochanter	·78
Coracoid, greatest breadth	·87
" inferior border to scapular margin	·54
" glenoid margin to foramen	·34
Presacral I, length of centrum	·39
" I, breadth of centrum	·37
" VI, length of centrum	·43
" VI, breadth of centrum	·35
Sacrum, breadth at second transverse process	1·12
" breadth at fourth transverse process	·88
" length of the four centra	·975
Thoracic rib, length	2·745
" " breadth across capitulum and capitellum	·54
Caudal II, height over all	·60
" " transverse breadth of centrum	·32
" " length of centrum	·155
" " height of spine above centrum	·32
" " height of spine above zygapophyses	·18

Relationships.

There have been four genera referred to the Sauropoda whose validity may be more or less called in question. These are *Atlantosaurus* and *Apatosaurus* Marsh, and *Camarasaurus* and *Amphicoelias* Cope. Some of these genera are certainly valid, others probably synonyms. The fact that three of the four are based upon scattered parts of skeletons of which no two have enough in common to make correlation certain, complicates the problem. Added to this is the uncertainty as to whether the type specimens represent one individual or more than one.

The genus *Camarasaurus* has usually been regarded as valid and as representing an extreme Morosauroid type. This con-

clusion is borne out by the presence of four ankylosed vertebrae in the sacrum, the subquadrate form of the coracoid, the relatively short tibia, the Morosaur-like thoracic vertebrae and the expanded blade of the scapula. Unfortunately there are parts of two skeletons represented in the type of *C. supremus*, which accounts for Cope's describing it as having twenty or more thoracic vertebrae.

There are reasons both for and against considering *Atlantosaurus* as a synonym of *Camarasaurus*. The size of the type specimens is almost identical, as is shown by the length of their respective femora. The similarity between the sacra holds so far as the number and size of the vertebrae are concerned. The one difference in evidence lies between the hollow centra described by Marsh and the solid structure of the same as stoutly maintained by Cope. The ischium of *Camarasaurus* is not known; that figured by Marsh is far from the Morosauroid type. Neither is the pituitary canal described in the skull of *Atlantosaurus* consistent with the characters which one would expect in this genus. The writer was in error in stating in a recent note on this form* that the type specimens of both genera came from the same locality. That of *Camarasaurus* was collected near Cañon City, Colorado, while the type of *Atlantosaurus* came from near Morrison, one hundred miles farther north.

Apatosaurus is clearly distinguishable from *Camarasaurus* by the narrow blade of the scapula if not by the doubtfully constant character of three coalesced vertebrae in the sacrum. With *Atlantosaurus* the sacrum forms the sole basis of comparison. If it be conceded that the primitive dinosaurian sacrum is made up of three coalesced vertebrae, we may fairly assume that the *Apatosaur* type represents merely a young specimen of *Brontosaurus*. The size of the specimen, the straight blade of the scapula, the imperfectly ossified border of both scapula and coracoid and the character of the dorsal vertebrae all bear out this conclusion.

Amphicoelias is unique in the length and slenderness of its femur. The biconcave type of caudal centrum is common to a number of Sauropod genera; but that this type of vertebra persisted throughout the thoracic series may well be questioned. The closest affinities of this genus seem to be with *Diplodocus*.

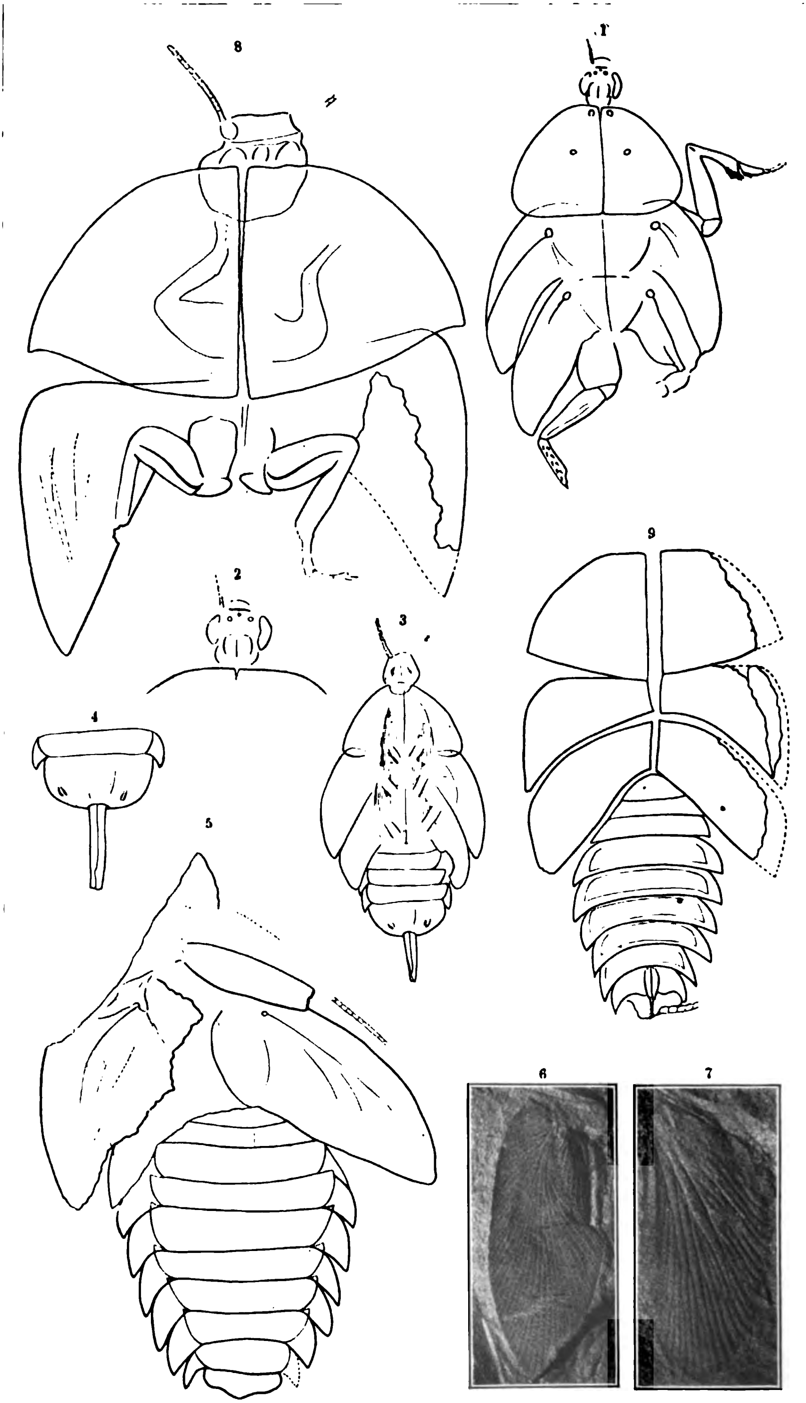
In view of this complexity of uncertain relationships, little can be said of the affinities of *Brachiosaurus*. As the humerus in the most nearly allied genera is not known, the fore leg offers no basis of comparison other than the coracoid. This bone differs from that of the type *Camarasaurus supremus* in

* Field Columbian Mus. Pub. Geol. Ser., vol. i, No. 10.

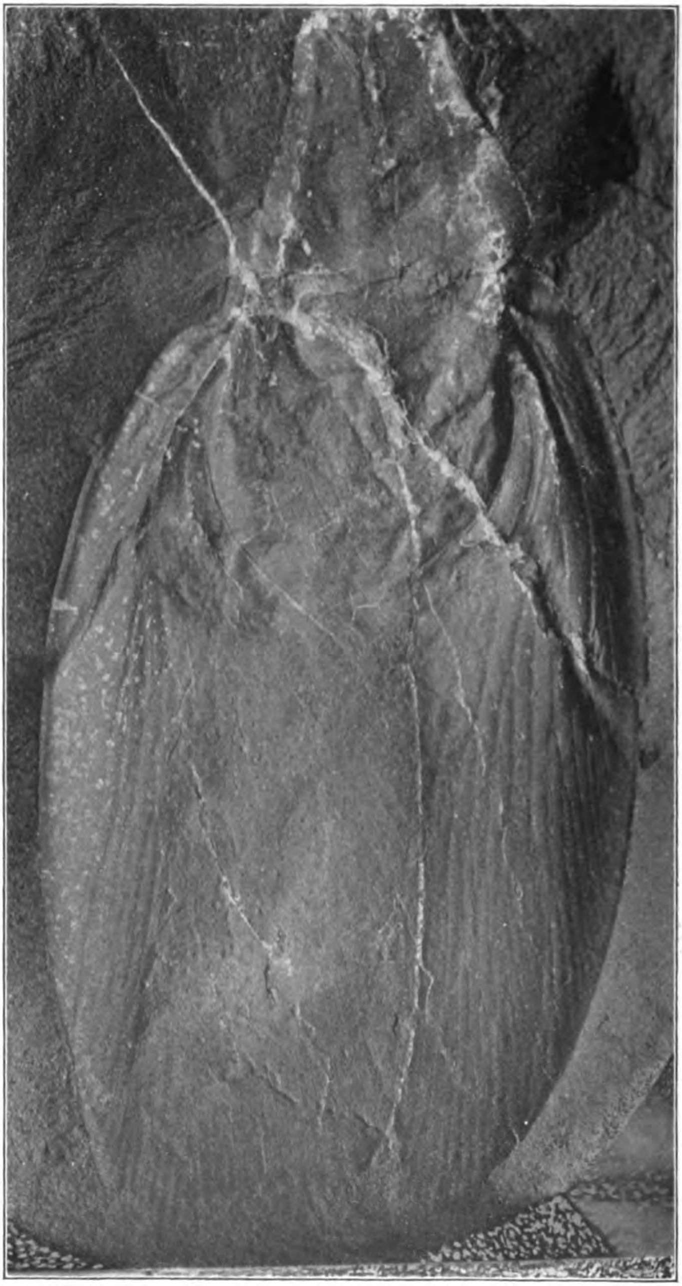
its greater length, its subovate outline, the lateral direction of its glenoid surface and the proximity of the same to the surface for sternal articulation. The femur is considerably longer, but making allowance for distortion the two could not be generically distinguished. The sacra differ in the presence of small cavities in the centra of this form. The anterior caudals of both are biconcave, their diapophyses similar, but the neural spine in *Camarasaurus*, according to Cope's measurement, is fully twice as long as that of this specimen. The essential difference in the vertebrae lies in the thoracic centra. Those of *Brachiosaurus*, as has been pointed out, range from 39 to 43 centimeters in length and from 37 to 35 centimeters in breadth. A "lumbar" vertebrae of *Camarasaurus* is described by Cope as being 17 centimeters in length and 42 in breadth. This difference alone would seem to warrant generic distinction. If *Atlantosaurus* be regarded as a valid genus, there is not enough in common between its type specimen and this one to determine their relationships. *Amphicoelias* need hardly be considered in this connection.

The further description of the sacral and presacral vertebrae of *Brachiosaurus* will be taken up in another paper. It is to be hoped that their removal from the matrix and careful study will establish the position of this genus.

Field Columbian Museum, Chicago.



Nymphs and Wings of Carboniferous Cockroaches.



CARBONIFEROUS COCKROACH, MEGABLATTINA. × 2.

Art. XXXI.—*Some New Structural Characters of Paleozoic Cockroaches;** by E. H. Sellards. (With Plates VII and VIII.)

The relatively large number of cockroaches that have been obtained from rocks of Carboniferous age indicates that these insects were extremely abundant even at that early time. The Paleozoic species, however, have been known heretofore, for the most part, from the wings alone, and of these only the more resistant front wings, or tegmina, are as a rule preserved. The more perishable organic matter of the body no doubt hastens its decay. The wings, on the other hand, are almost devoid of destructible organic matter, and at the same time their strong framework of veins makes them fairly resistant. Various contemporaneous and associated animals, such as small batrachians, spiders, and dragon-flies, doubtless fed then as now upon the bodies of insects, and some of them may have even acquired the well-known habit common to ordinary bats, modern dragon-flies, and some recent spiders, of biting off and rejecting the wings of the insects on which they prey. When detached, the wings are easily carried by currents of water, and are thus readily transported into places where permanent deposits are accumulating.

The distinctions between Paleozoic and recent cockroaches were originally based almost entirely on the framework of the front wings.† Some additional knowledge of other parts of the body has since been obtained, although acquired slowly, owing to the scarcity of favorably preserved specimens. A good deal of instructive material, however, has now accumulated, both from fuller collections from old localities and the discovery of new ones.

It is almost a decade since the appearance of Professor Scudder's last important contribution to the knowledge of Paleozoic cockroaches. In the meantime the interest in early types of insects has been greatly increased through the study of recent forms, and especially through a better understanding of the homologies of the wing veins in the different orders. The common primitive ancestor of all winged insects, or the nearest approach to such a form, is naturally to be sought in Paleozoic rocks. A return to the study of the early representatives of the cockroaches in the light of new and rich material seems, therefore, especially opportune at this time.

The writer has in preparation a study of the structure of Paleozoic cockroaches, including a description of new forms

* The present paper is for the most part taken from a more extended study of American Paleozoic cockroaches, now in preparation.

† Scudder, Mem. Boston Soc. Nat. Hist., vol. 3, pp. 23–134, 1879.

from the Coal Measures. The paper is now nearing completion, but as some time will necessarily elapse before its publication, it seems best to give in advance the results of more immediate interest.

The material on which this study is based is mostly of Coal Measure age, and is contained in the collections of the Yale University Museum, the University of Kansas Museum, the National Museum, and in the private collection of the writer. The principal localities represented are Mazon Creek, Illinois, and Lawrence, Kansas.

From the favorable preservation of the fossils contained in these large collections, it has been possible to give a more complete account of the structure of Paleozoic cockroaches than has been given heretofore. Additions have been made to a knowledge of the structure of the head, antennæ, eyes, legs, hind wings, dorsal and ventral sides of the abdomen, ovipositors, and cerci. The larval stages of several species have also been discovered.

The head is more or less completely preserved on a number of specimens. Occasionally the eyes and antennæ, which have not been previously observed, are present. The cerci vary a good deal in length in the different genera and species, and are directed either obliquely or at right angles to the body.

Nymphs.—An unusual feature of these collections is the comparative abundance of cockroaches in the immature or nymph stages, or, rather, in most cases the sheddings or moults of nymphs. That these fossils represent nymphs and not wingless adults is evident not only from the presence of the same species in different stages of development, but also from the fact that a number of them are referable to their adult genera and species, while most of them have an open slit down the thorax, indicating that the part preserved is the cast-off integument. These moults are particularly well adapted for preservation, as on the one hand they are free from the injurious effects of the organic juices of the body, and on the other escape the danger of being eaten by other animals. The chitin is hard and resistant, and yet the moults are light and like the detached wings are readily carried by currents.

The presence of nymphs at localities where the wings only of adults are found, or where the bodies are but rarely preserved, is probably to be accounted for in this way. It is extremely rare to find any part of the body of an adult insect, other than the wings, in the Lawrence Shales. Nymphs, on the contrary, as well as detached wings, are comparatively numerous. The Mazon Creek nodules contain not only the moults, but occasionally the bodies as well. Not a few of the nymphs can be identified with their proper genera and species.

Etoblattina mazona is now known in several stages, from a young age to the adult condition* (Plate VII, figures 1–4). The nymph stage of *Mylacris elongata* has also been recognized with a fair degree of certainty. As in recent Orthoptera, the young resemble the adults, growth taking place by a succession of moults. The wings appear gradually, and certain other changes similar to those seen in existing cockroaches, as the gradual rounding out of the posterior margin and angles of the pronotum can be traced.

An important part of the data regarding the structure of the body and appendages has been obtained from the nymphs, and from these also it has been possible to clear up the much misunderstood genus *Dipeltis*. This fossil, which has been variously referred to the xiphosuran and phyllopod crustaceans, is in reality an immature cockroach of the tribe Mylacridæ and probably of the genus *Mylacris*.† Through the kindness of Mr. Charles Schuchert, the type of *Dipeltis* together with the other National Museum material has been accessible for study. The contrast between fossil and matrix in the Mazon Creek nodules is often not well marked, and structural characters, which when once discovered are perfectly evident, are in danger of being at first overlooked, especially when only a few specimens are at hand for study. This has been particularly true of *Dipeltis*. The type specimen preserves, in fact, besides the prothorax and first pair of wing pads, the head, antennæ, and the first and second pairs of legs (Plate VII, figure 8). About half of the head projects in front of, and the remainder is seen in outline through, the pronotum. The left antenna, which is now more completely uncovered, is apparently joined to the head by an enlarged socket-like attachment resembling that of modern cockroaches. The segments are numerous. Those near the base are wider than long; farther out they become as long or longer than wide. The first pair of legs is seen indistinctly through the pronotum. The femora of the second pair are well preserved. They are smooth, stout, and of moderate length. The trochanters are less distinct, and only indications of the coxæ are to be seen. The tibiæ are somewhat longer than the femora. Part of the right tarsus is preserved. The first segment is comparatively long. Those following are indistinct.

The true nature of *Dipeltis* was, indeed, suspected by Gahan,

* The evidence for the generic and specific reference of the nymphs, in so far as they have been identified, will be given in the completed paper. In the case of *E. mazona*, the connection is quite satisfactorily established.

† This statement refers to the type species of the genus, *Dipeltis diplodiscus* Packard (Amer. Nat., vol. 19, p. 293, 1885; Mem. Nat. Acad. Sci., vol. iii, p. 145, 1886). The second species, *Dipeltis Carri* Schuchert (Proc. U. S. Nat. Mus., vol. 19, p. 671, 1897), from the illustration, appears to the writer to belong with *Etoblattina mazona* (cf. Plate VII, figures 1 and 3 of this paper).

who from illustrations alone compared the fossils with some coleopterous larvæ, and at the same time called attention to their striking resemblance to the nymphs of cockroaches.*

Beecher, although his results were not published, recognized *Dipeltis* as a nymph cockroach, and made plaster casts of living nymphs to show the close similarity. Over fifty specimens of nymphs cockroaches in various stages of development have now been obtained, and these have been very useful in the present study.

Structure.

Although the modern cockroaches are comparatively generalized insects, yet in important respects their Paleozoic ancestors were of a much more generalized structure, the adults retaining some characters now to be seen in the nymph stages only. The most marked changes since Paleozoic time have occurred in the front and hind wings, the abdomen, and the ovipositors.

Front Wings.—The tegmina have been thoroughly studied by Scudder and others, and compared with the front wings of living cockroaches.†

Hind Wings.—The more delicate hind wings are rarely preserved, but a considerable number have been obtained, especially from the Kansas deposits. The costal border is nearly straight, or often a little concave in the proximal half and rounded to the apex in the distal half (Plate VII, figure 7). The anal area was not so largely developed and, as Scudder has noted, did not possess the fanlike plaiting seen in almost all modern cockroaches.‡

The longitudinal fold between the cubital and anal areas, which is common to the recent cockroaches, does not seem to have occurred in any of the Paleoblattidæ. Several specimens are now known with the wings still in their natural position over the abdomen. In all of these cases, and also when found detached, the wings are always spread full width. It should be added, however, that a large undescribed species in the writer's possession, from the Upper Coal Measures, presents some indications of the doubling under of a part of the anal area, but in no instance is the fold between the cubital and anal veins. The main veins of the hind wing are more evenly developed than in most of the living forms. The first main vein, or costa, which is simple and usually marginal in the adult condition of living insects, is not only some distance from the margin, but in the more primitive Mylacridæ, and occasionally in the Blattinariæ, gives off a few superior branches. This

* Natural Science, vol. xii, p. 42, January, 1898.
† Mem. Boston Soc. Nat. Hist., vol. iii, pp. 23–134, 1879, and elsewhere.
‡ Mem. Boston Soc. Nat. Hist., vol. iii, p. 322, 1885.

character can be best observed on the two hind wings of the type specimen of *Promylacris rigida* Scudder, the matrix covering the borders having been removed for this study. The wing is strengthened as in living forms by a deep fold along the costal border. The area in front of this fold is apparently broader in the Mylacridæ than in the other tribe. Cross veins, except for the wavy reticulation of the membrane, seem to have been absent.

Abdomen.—The seventh, eighth, and ninth terga of the abdomen of Paleozoic cockroaches were evenly developed, at least in all the nymph stages, presenting in this respect a marked contrast to the common living forms in which the corresponding terga of both sexes have undergone more or less reduction. The lateral edges of the terga are well developed and project freely from the edge of the body.* The sterna of a number of specimens have been observed. They are seen either as impressions through the terga, or, the terga having been removed, are viewed directly. The seventh sternum of the female is enlarged, rounded posteriorly, and has projecting from beneath it (when viewed from the ventral side) a long ovipositor† (Plate VII, figures 3 and 4).

In the tribe Mylacridæ the sterna in front of the seventh resembles the terga in shape, being rounded in front and at the anterior corners and pointed at the posterior corners (Plate VII, figure 9). The corresponding terga of *Etoblattina*, and probably of most of the Blattinariæ (with the apparent exception of *Spiloblattina*) are, on the contrary, concave and pointed in front and rounded at the posterior border (Plate VII, figures 3 and 5).

The position of the eighth and ninth sterna of the female has not been observed. In the recent cockroaches, however, the first pair of ovipositors is attached to the eighth sternum, which is reduced and telescoped within the seventh. Such was doubtless the case, also, in the ancestors of these forms, as indicated by the ovipositor passing on the inner side of the seventh sternum. The double fold in the ventral integument, which forms the characteristic genital pouch of the modern cockroaches, seems therefore to have originated as early as the Carboniferous, although the pouch could hardly have been so perfectly developed at that time.

Ovipositor.—The ovipositor is present on several specimens. The parts of this organ in one very young individual of

* Woodward has described a nymph from the Coal Measures of Scotland, on which similar characters of the terga are noted (Geol. Mag., Decade 3, vol. iv, pp. 433–435, 1887).

† The presence of an ovipositor on Paleozoic cockroaches was first noticed by Brongniart (Comptes Rendus, Feb. 4, 1889, vol. cviii, p. 252), but has not been previously observed on American specimens.

Etoblattina mazona (to be figured later) have apparently not yet united and present a striking resemblance to the early stages in the development of the ovipositors of the Locustidæ, as figured for *Locusta* by Dewitz.* From this specimen it appears that the ovipositor is composed of probably three pairs, of which the inner is the smallest. In later stages when the three pairs have become united, the component parts are indicated by a groove down the center (Plate VII, figures 3 and 4).

New Forms.

A number of new forms have been obtained and are described in manuscript. One of these (Plate VII, figure 6) is remarkable among cockroaches of the Coal Measures, not only for the presence of numerous comparatively strong cross bars in the tegmina, but especially for the course of the anal veins, most of which end on the anal furrow. The latter character has not been previously observed on any member of the Paleoblattidæ, and the former but rarely.

A new genus from Mazon Creek is of interest because of the shape of the pronotum and the unusual size of the type species, which is by far the largest known Paleozoic cockroach. The type specimen measures not less than three and one-half inches (9^{cm}) from the anterior margin of the pronotum to the tips of the wings. The width of the body including the wings is one and one-half inches. The abdomen is long, thick, and bulky. The pronotum, unlike that of any other described Paleozoic genus, is nearly rectangular in shape, truncated in front, and enlarged and rounded at the base. The lateral margins are not quite parallel. The sides at first converge, but expand at the front border. A median line extends down the center. The wings are longer than the abdomen. The costal border of the front wings is slightly and regularly arched. The type of venation is that characteristic of the tribe Blattinariæ. The subcostal area is narrow and extends about two-thirds the length of the wing. Numerous superior veins are given off from the main stem. The radius is strong. A superior branch is given off near the base, and a few others farther out. The median area is small. The cubitus, on the other hand, is well developed, extends to near the inner angle of the wing, and gives off numerous inferior branches. The hind wings, the tips of which are seen, are apparently of about the same length as the front.

The name *Megablattina* is suggested for the genus, and *M. Beecheri* for the type species (Plate VII).

* Zeit. für wiss. Zool., vol. xxv, p. 176, pl. 12, figs. 1–11, 1875.

The fragment of a front wing from the same locality, mentioned by Scudder* "to draw attention to an unknown species remarkable for its immense size" is probably of the same species.

The large hind wing also from Mazon Creek, described and figured in the same memoir (l. c., p. 142), doubtless belongs to this genus and species. Scudder says of this wing: "A single specimen of a hind wing of enormous size differs so much from any other known that I use for it, as a convenience merely, the old generic term Blattina, as applied to fossil cockroaches in general." The estimated length, 51^{mm}, is approximately the size to be expected for the hind wing of a small individual of this species.

General Considerations.

The most important differences between the Paleozoic and recent cockroaches have already been indicated. Evolution within the group, although not rapid considering the lapse of time since the Paleozoic, has been progressive and directly in the line of increased specialization and differentiation of the organs affected. In both the front and the hind wings, there has resulted a less equal development of the main veins. There has also occurred in both wings, a migration of the main trunks of the veins toward the costal border, with a consequent reduction in the superior branches of these veins and the area occupied by them, as will be seen by comparing the more primitive Mylacridæ with the Blattinariæ. Cross veins, which rarely occur in the front wings, and so far as known are absent from the hind wings of Paleozoic forms, have since become almost universal in both wings.

Not only have both wings departed more widely from the primitive type but differentiation between the front and hind wing has increased as well.† The front wings have become, as a rule, more resistant, although there were species in the Carboniferous with wings more opaque than some of our living thin-winged species. The hind wings have developed a longitudinal fold and plaiting and an increased expanse of the anal area.‡

Important changes have occurred in the abdomen. The terga and sterna have become modified, tending towards a reduction of the number of abdominal segments. The genital pouch has been perfected, and the ovipositors have become reduced and adapted to perform a specialized function.

On the other hand, there are certain broad resemblances which should not be overlooked, implying as they do a close

*Bull. U. S. Geol. Surv., No. 124, p. 55, 1895.

†See also Scudder, Mem. Boston Soc. Nat. Hist., vol. iii, p. 320, 1885.

‡A few recent genera have developed in addition to the longitudinal fold a transverse fold of the hind wing.

genetic connection between the ancient and modern forms, the one standing in direct ancestral relation to the other. The body had essentially the same shape. The legs indicate the same habit of locomotion. The broad pronotum was as characteristic a feature of the Carboniferous as of the recent cockroach, and formed quite as secure a shelter for the small retractile head. The front wings had a similar arched form, and the anal area was as well defined.

In view of the fundamental and close relations, it seems evident that the Paleozoic and recent cockroaches constitute two nearly related and intergrading groups of a single order Orthoptera, or, more accurately, two stages in the evolution of a single phylum. Recent studies have brought to light some new structural differences separating the two stages, without, however, impairing the evidence of their interrelation. On the other hand, the discovery of a form in the Carboniferous with anal veins ending on the anal furrow and with strong cross veins tends to break down apparent differences. The very late Paleozoic and early Mesozoic species, when better known, may confidently be expected to furnish other intergrading characters.

The venation of the immature wings of modern nymph cockroaches is very similar to that of Paleozoic adults.* The modern nymphs thus present in their development an instructive recapitulation of ancestral characters.

The long ovipositor of Paleozoic cockroaches apparently indicates that a well-developed ovipositor is a primitive character of the Orthoptera, the reduction of this organ in the modern Blattidæ, like the characteristic egg case and genital pouch, being an expression of a specialized condition of the external genital organs. Some other families of the order, as the Locustidæ, are, as regards the ovipositor, less differentiated from the original type than are the cockroaches.

The plication of the anal area, so constant a feature of the hind wings of modern Orthoptera, is likewise, as Scudder maintains, a comparatively recent acquisition.

It is worthy of remark that the plication, as also the fold, of the hind wing of cockroaches developed subsequent to their differentiation as a distinct phylum. A comparatively broad anal expanse creating the need of a plication was, however, doubtless common to the early Orthoptera, but both the plication and the fold have originated independently in more than one division of the order. The same is true of cross veins. It is probable that at the time cockroaches were differentiated,

* Compare, for instance, the venation of the wing of a typical Paleozoic adult cockroach with that of recent nymphs, as given by Packard (Text Book of Entomology, p. 138, 1898; or, Comstock and Needham, Amer. Nat., vol. xxxiii, p. 574, 1899).

well-marked cross veins were entirely lacking in both wings; now, on the contrary, cross veins are numerous and not unlike those of other Orthoptera.

The plications are developed, doubtless, largely in response to mechanical principles. Mechanical need, also, has probably had an important influence in developing cross veins. The interchange of circulating fluids in the wing, tending to follow within established paths, may also, in some cases, have resulted in the origin of cross veins.

The writer is indebted to the kindness of Dr. S. W. Williston for the opportunity of studying the collection of cockroaches made for the University of Kansas Museum. Mr. Charles Schuchert has very generously supplied valuable material for study from the United States National Museum. Acknowledgments are especially due to Prof. C. E. Beecher for assistance in the study of Paleozoic cockroaches and in the preparation of the present paper.

Yale University Museum, New Haven, Conn.

EXPLANATION OF PLATES.

Plate VII.

Figures 1–4.—*Etoblattina mazona.* The first specimen figured is nearing maturity. Traces of the venation are seen, and a thickened circular area indicates the place at which the joint of the wing is to be formed. The tibiæ, as indicated, are spinous. The head, drawn enlarged in figure 2, is small. The eyes and a part of the left antenna are preserved. The second specimen, figure 3, of a younger stage, seen from the dorsal view, has the terga removed except at the edges, thus exposing the sterna. The ovipositor is seen to pass on the inner side of the enlarged seventh sternum. The obverse side of the nodule shows all ten of the terga and the cerci. From Mazon Creek, Illinois.

Figure 5.—*Etoblattina* sp. The abdomen of this species is large. In the flattened condition of the fossil the sterna show distinctly as impressions through the terga. The lateral edges of the terga are prominent. The specimen was obtained from the Upper Coal Measures, at Lawrence, Kansas.

Figure 6.—Front wing of an undescribed species from the Upper Coal Measures of Kansas. Most of the anal veins end on the anal furrow, and the wing has numerous cross veins.

Figure 7.—Hind wing from the Upper Coal Measures of Kansas.

Figure 8.—Re-illustration of the type specimen of *Mylacris* (*Dipeltis*) *diplodiscus.* The relative distinctness of some of the structures is necessarily exaggerated in the pen drawing. The head is comparatively large.

Figure 9.—Moult of a Mylacrid nymph. The sterna with their pointed posterior angles are seen as impressions through the terga. The cerci of this species stand at right angles to the axis of the body. Figures 8 and 9 represent specimens from Mazon Creek, Illinois.

Figures 1–7 are of the tribe Blattinariæ; figures 8 and 9 represent nymphs of the Mylacridæ. Figures 2 and 4 are enlarged four times; figure 8 is three times natural size; all the others are twice natural size.

Plate VIII.

Megablattina Beecheri, gen. et sp. nov. Twice natural size.
From Mazon Creek, Illinois.

ART. XXXII.—*The Bath Furnace Meteorite;* by HENRY A. WARD.

WE are fortunate in the addition of another—the third—to the number of meteorites which have fallen to earth in the year just past and are on record.

On the evening of November 15, 1902, at about 6.45 o'clock, a brilliant meteor was seen by many persons in the States of Louisiana, Mississippi, Alabama, Georgia, Tennessee, Kentucky, and Ohio, in its progress from southwest to northeast over a course of more than six hundred miles. Its passage was simultaneously noticed by two trained observers—Professor A. H. Miller of the State College at Lexington, Kentucky, and Professor H. C. Lord of the Emerson McMillan Observatory of Columbus, Ohio. These gentlemen both secured the altitude and azimuth of the point where it appeared to burst and vanish, as seen from their rather widely separated standpoints. Calculations based upon these observations gave the approximative place of the fall—where, indeed, it had already been announced—as in Bath County, Kentucky. The detonations which immediately preceded its descent to the earth were heard over a large area in that region, most persons thinking that they were due to the explosions of nitroglycerin, which is often used in "shooting" wells in the neighboring Ragland oil fields.

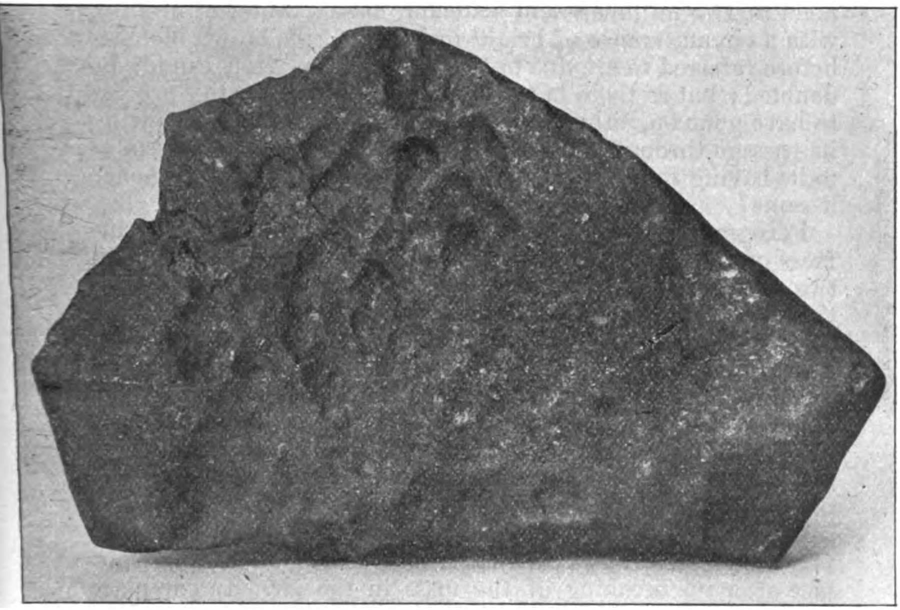
The aerolite—for such it was—came to the earth in the extreme southern part of Bath County, at an old settlement called Bath Furnace. It struck in the middle of the road, directly in front of the home of Mr. Bluford Staton. Mr. Staton and his wife at once made search for it, but on account of the darkness they failed to find it that night. The next morning, however, Mr. Staton readily discovered the meteorite lying on the surface of the ground on the side of the road, whither it had bounded. It had lost some small chippings by the collision of its fall, but was in the main quite entire.

Mr. Staton in a letter tells me: "It was dark. I saw the light and heard the report. It came through the air, whizzing like a steam-saw going through a plank. * * * The stone struck in the middle of our hard road and bounded away for about five feet to one side. The hole which it made in the road was about one foot long, nine inches wide, and five inches deep."

The aerolite is in general shape a five-sided polygon, somewhat wedge-shaped when viewed from either the side or the end aspect. Its length is 8¼ inches, height 6½ inches, width 4¾ inches. The weight of the mass is 12 lbs. 13½ ounces.

The chippings broken off in fall, if added, would doubtless make its total weight just 13 lbs. Its specific gravity is 3·48.

The stone is covered over its entire surface with a very dark —nearly black—crust. This crust, although absolutely opaque and protective, shows itself at the few fractured spots to be very thin—less than half a millimeter thick. It is dull and matte in surface appearance, with a uniform, fine granulation. This is, however, broken at frequent points by minute pimples,



interspersed with equally minute angular or slightly lengthened protuberances. None of all of these have an elevation of more than one millimeter. These pimples, where they have been rubbed, show a bright character, and are undoubtedly outside individuals of the minute points of bright iron which are sprinkled somewhat abundantly through the entire stone mass.

The inner structure of the stone, as shown in a section, is quite compact and dense, taking a good polish. It is a light gray base, blotched evenly throughout with patches of clove-brown iron oxide. Most of these are cloud-like, in indefinite contour; but a few, ranging from one to three millimeters in diameter, are round, and seem to be limited to the decomposition of a single previous iron enclosure. Very few defined chondri are detachable.

The whole mass is sprinkled liberally throughout with bright iron particles. Most of these are distributed as a bright star constellation ; but among them are scattered a small number which are from one to four millimeters in diameter, mostly of irregular, angular shape. In several instances these are broken sharply in two, and are crossed by granular troilite, fine-grained and fresh shining. One of these is a six millimeter triangle in which the three points only are of bright nickel-iron, while the balance is troilite. In two other cases, nodules, two millimeters in diameter, have a center of troilite, with a circumference of bright iron. That the brown blotches before referred to are due to the oxidation of iron cannot be doubted ; bnt as there has been no opportunity for this process to have gone on, either since the fall of the stone or during its passage through our atmosphere, the question is raised as to its having found the oxygen in the parent body from whence it came?

Pezographs, or finger-mark pittings, are visible on all surfaces of the mass, yet varying notably on different sides. On two sides they are few in number, and only dim depressions—though still unmistakable in their nature. On the other three surfaces they are frequent, and are three to five millimeters in depth, with area as large as the end of an adult human finger. Some few are independently placed, but most of them are confluent, and show the line of movement of the mass through the furrowing air. One notable gathering is curiously like the crowded tracks of three or four kittens' feet. Two of the smaller sides of the mass have a very different pitting,—that thickly crowded rain-drop appearance which is often found on a secondary crust which has formed on a fresh surface after the breaking of the mass in the air. In one place there is a furrow one and one-half inches long and two to four millimeters deep and wide, with walls of overhanging crust. So far as examination has yet been carried, this new aerolite presents no features of form or of composition which are materially different from others of its class. A careful petrographical examination may, however, reveal something of especial moment. The relation of the intruding troilite to the riven particles of nickel-iron certainly merits further investigation.

At my request, Professor Merrill of the National Museum has kindly made a couple of slides of the mass, and reports as follows : "The stone consists essentially of olivine and pyroxene, with the usual metallic sprinklings and troilite. There is present also in small quantities a completely colorless, almost isotropic mineral, which is probably maskelynite, although, if such is the case, it is a product of original crystallization and has not been altered by fusion, as suggested by Tschermak.

The mineral is in too small quantities to be determined accurately from the two sections which I have thus far prepared. The stone is chondritic, but the chondrules show no disposition to separate from the groundmass, and I am inclined to classify it with Brezina's intermediate chondrites (CI)."

The date of fall of this meteorite—November 15th—will not be overlooked. It comes as one of the Leonids whose orbit our earth cuts yearly, as it has been known for a full thousand years to do, on that date. This, as also the Saline Township, Kansas, aerolite (1898), fell on the same day of the month. These (as also Trenzano—November 12, 1856, and Werchne Tschirskaja—November 12, 1843) would seem to belong to the great Leonid stream, estimated by astronomers at many millions of miles in length, which at these dates we have cut at one of its sparse portions, picking up only stragglers in place of the millions which have shown themselves in the dates of thirty-three or thirty-four years apart, when we met with the immense bulk of the stream. It is well known, however, that in the very acme—so to call it—of these greatest of meteor-showers — 1766, 1799, 1833, 1866 — the number of meteorites which have reached our earth has not been greater than at other periods (of three days) in the year. Bath Furnace (for so we will call this stone) is still none the less suggestive as a Leonid.

Professor Farrington has already called attention (*Science*, July 11, 1902) to the fact that of the three above-mentioned meteorites which have thus far been known to fall at the time of the Leonid showers, all have had a nearly similar structure, —veined globular chondritic (CCA). We regret that Bath Furnace should not wholly coincide in this feature with the other three known Leonids (?).

Bath Furnace adds a twelfth one to the meteorites which are to the credit of the State of Kentucky. Only two of these are stones, and both of them (Cynthiana and Bath Furnace) have fallen in closely adjoining counties, only about forty miles apart. This, with an interval of twenty-six years.

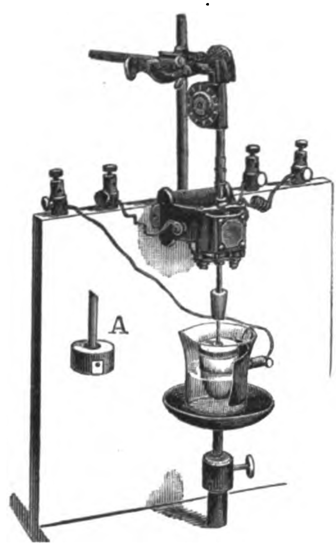
We omitted to say in its proper place in this article that this Bath Furnace meteorite passed promptly from the hands of the finder, Mr. Bluford Staton, to those of Mr. W. H. Dougherty, who in turn deposited it for sale with Professor A. M. Miller in Lexington. From him the writer duly obtained it, and has given it a place among the other 302 aerolites (stones) which make an important part of the Ward-Coonley Collection of Meteorites now on deposit and display in the American Museum of Natural History in New York.

620 Division St.,
Chicago, Ill.

ART. XXXIII.—*The Use of a Rotating Cathode in the Electrolytic Determination of the Metals;* by F. A. GOOCH and H. E. MEDWAY.

[Contributions from the Kent Chemical Laboratory of Yale University—CXV.]

THE rotating cathode has been applied usefully in the arts for the purpose of securing compact metallic deposits in electro-plating. In this case a soluble anode is employed and the electromotive force of the current is generally low. So far as we are aware, however, no attempts have been made heretofore



to apply the rotating cathode in analytical separations, in which it is the object to remove the metal completely from solution. In such processes the soluble anode is not used, and the comparatively high electromotive force necessary to overcome the resistances and to throw down the metal with rapidity liberates hydrogen from the water solution simultaneously with the metal, and the consequence is the production of a deposit lacking in compactness and adhesiveness. This interference on the part of the evolved hydrogen with the regularity of deposition appears to be the chief reason why low intensity and low density of current must be used in the ordinary electrolytic processes of analysis. We have made some experiments, therefore, to see whether it is not possible to so far avoid the interfering action of hydrogen by the use of the revolving cathode as to secure with high currents and in a short time deposits sufficiently adherent and homogeneous for analytical purposes. The results, as will appear, are successful.

For a cathode we have used an ordinary 20^{cm^3} platinum crucible rotating at a speed of from 600 to 800 revolutions a minute. The crucible is driven by a small, inexpensive electric motor fastened so that its shaft is vertical. Upon this shaft the crucible is fixed by pressing it over a rubber stopper bored centrally and fitted tightly on the end of the shaft (fig. A). To secure electrical connection between crucible and shaft, a narrow strip of sheet platinum is soldered to the shaft and then bent upward along the sides of the stopper, thus putting the shaft in contact with the inside of the crucible when the last

is pressed over the stopper. The shaft is made in two parts as a matter of convenience in removing the crucible and is joined, with care to make a good contact between the two pieces of shafting, by a rubber connector of sufficient thickness to prevent the crucible from wabbling when rotated.

The solution to be electrolyzed is placed in a beaker upon a small adjustable stand, so that the crucible may be dipped into the liquid to any desired depth. A platinum plate is employed as an anode, and this is connected to the positive pole of a series of four storage batteries, while the negative pole of this series is connected to the bearing in which the shaft rotates, thus allowing the current to go from the platinum plate through the solution to the crucible, up the shaft of the motor and back to the batteries.

The power to run the motor is taken from the incandescent light circuit of the street.

The first attempts were made with the deposition of copper from a solution of the sulphate, and the procedure was as follows: The solution, 50^{cm^3} in volume, was placed in a 150^{cm^3} beaker and acidulated to give better conductivity. The stand carrying the beaker was raised until the liquid covered about two-thirds of the crucible adjusted to the shaft, thus giving a cathode surface of about 30^{cm^2}. The anode was introduced and the motor started. The wires from the storage batteries were connected and the current allowed to pass through the solution. The duration of the electrolysis was varied according to the strength of current used, but in each case, after the deposit was nearly complete, the current from the batteries was shut off, the motor stopped and the sides of the beaker, the platinum anode, and the crucible were carefully washed with a fine jet of water, the motor was again started and the current allowed to pass for the remaining time.

When the deposit was complete the crucible was removed and washed, first with water, then with alcohol, and finally was dried by passing it over a flame.

Sulphuric acid [6 or 7 drops of the dilute acid—1 : 4] was generally used to acidulate the solution, since it was found that the copper was deposited in a shorter time with sulphuric than with nitric acid present. A few experiments were made in which small amounts of nitric acid were used to show that the copper could also be deposited completely in presence of this acid.

The following table show the results of a series of experiments made as described above in solutions acidulated with sulphuric acid. The standard of the solution of copper sulphate was fixed by the usual slow method of electrolytic analysis.

TABLE A.

	Copper taken. grm.	Copper found. grm.	Error. grm.	Current. amp.	N D 100.	Time.
1	0·0651	0·0652	+0·0001	0·8	2·7	25 min.
2	0·0651	0·0652	+0·0001	0·8	2·7	15 "
3	0·0651	0·0651	0·0000	1	3·3	10 "
4	0·0651	0·0649	−0·0002	1	3·3	10 "
5	0·0651	0·0658	−0·0003	1	3·3	10 "
6	0·1272	0·1272	0·0000	2·5	8·3	15 "
7	0·1272	0·1271	−0·0001	2·5	8·3	15 "
8	0·1272	0·1271	−0·0001	2·5	8·3	15 "
9	0·1272	0·1270	−0·0002	3	10	13 "
10	0·1272	0·1268	−0·0004	3	10	12 "
11	0·2548	0·2548	0·0000	3	10	20 "
12	0·2548	0·2548	0·0000	4	13·3	20 "
13	0·2548	0·2550	+0·0002	4	13·3	20 "
14	0·2548	0·2546	−0·0002	4	13·3	15 "
15	0·2548	0·2545	−0·0003	4	13·3	15 "

That the copper can be completely deposited, though more slowly, from a solution acidulated with nitric acid, is shown in the following tables. In the experiments of Table B the solution contained 6 drops of dilute [1 : 4] nitric acid, and in those of Table C 9 drops.

TABLE B.

Copper taken. grm.	Copper found. grm.	Error. grm.	Current. amp.	N D 100.	Time.
0·0651	0·0648	−0·0003	1	3·3	35 min.
0·0651	0·0652	+0·0001	0·8	2·7	30 "
0·0651	0·0650	−0·0001	0·8	2·7	25 "
0·0651	0·0649	−0·0002	1	3·3	25 "
0·0651	0·0650	−0·0001	0·8	2·7	25 "

TABLE C.

Copper taken. grm.	Copper found. grm.	Error. grm.	Current. amp.	N D 100.	Time.
0·0651	0·0652	+0·0001	1	3·3	35 min.
0·0651	0·0648	−0·0003	1	3·3	30 "
0·0651	0·0650	−0·0001	1·5	5	25 "
0·0651	0·0650	−0·0001	1·5	5	25 "
0·0651	0·0647	−0·0004	1·8	6	20 "

The rapid deposition of silver was next tried. To a 50^{cm^3} solution of $AgNO_3$ was added enough potassium cyanide to dissolve the AgCN first formed. Three cm^3 of dilute sulphuric acid were run in and enough ammonia to make the solution strongly alkaline. The method of manipulation was exactly the same as in the case of copper.

The following table records the determinations made with a solution of silver nitrate standardized as the chloride.

TABLE D.

	Silver taken. grm.	Silver found. grm.	Error. grm.	Current amp.	N D 100.	Time.
1	0·0968	0·0966	—0·0002	1·8	6	15 min.
2	0·0968	0·0967	—0·0001	1·9	6·3	15 "
3	0·0968	0·0965	—0·0003	1·8	6	15 "
4	0·0968	0·0969	+0·0001	2	6·7	10 "
5	0·0968	0·0965	—0·0003	3	10	8 "
6	0·1898	0·1901	+0·0003	2·5	8·3	10 "
7	0·1898	0·1898	±0·0000	2·5	8·3	10 "
8	0·1898	0·1900	+0·0002	3·	10	10 "
9	0·1898	0·1893	—0·0005	2·5	8·3	10 "

The rapid deposition of nickel was equally successful. Nickel-ammonium sulphate was dissolved in 25$^{cm^3}$ of water and 20$^{cm^3}$ of strong ammonia were added. In this liquid about a gram of ammonium sulphate was dissolved and the solution was treated in the same manner as in the preceding experiments upon copper and silver. It should be especially noted, however, that the solution must be kept within the limits of volume indicated above, as further dilution lengthens the time necessary for complete deposition.

TABLE E.

	Nickel taken. grm.	Nickel taken. grm.	Error. grm.	Current. amp.	N D 100.	Time.
1	0·0954	0·0954	0·0000	1·5	5	30 min.
2	0·0954	0·0953	—0·0001	3	10	25 "
3	0·0954	0·0956	+0·0002	3	10	25 "
4	0·0954	0·0953	—0·0001	3·5	11·7	20 "
5	0·0954	0·0955	+0·0001	3·5	11·7	20 "
6	0·1738	0·1736	—0·0002	3·5	11·7	25 "
7	0·1738	0·1740	+0·0002	3·5	11·7	25 "
8	0·1738	0·1740	+0·0002	4	13·3	25 "
9	0·1738	0·1737	—0·0001	4	13·3	25 "
10	0·1738	0·1738	0·0000	4	13·3	25 "

From these results it is plain that nickel, like copper and silver, may be deposited with rapidity and completeness.

The metallic deposits of these metals obtained by means of the revolving cathode are sufficiently coherent and compact to permit accurate manipulation and weighing even when the current density on the cathode is very considerable and variable within wide limits. Other metals have been found to behave similarly and the results of further experimentation will be described later.

The advantages of this rotating cathode in analytical operations are obvious: the process as described is rapid, exact, and very simple. The apparatus required, moreover, is inexpensive, and, if it is desired to make many determinations simultaneously, a single motor may be made to drive a running belt over any reasonable number of rotating shafts.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Qualitative Separation of Arsenic, Antimony and Tin.*—James Walker describes the following method for the analysis of this group: The sulphides are dissolved in caustic soda and the solution is boiled with sodium peroxide. This produces sodium stannate, arsenate and antimonate. An excess of ammonium chloride is then added, and the liquid is boiled. This treatment precipitates all the tin as stannic hydroxide, and, although the precipitate may contain a little antimony, the separation answers for qualitative purposes.

In separating the sulphides under consideration from the sulphides of the copper group by the use of sodium hydroxide, it is necessary to add a few drops of yellow ammonium sulphide in order that stannous sulphide may readily dissolve. It is to be noticed, also, that mercuric sulphide is soluble in the solution, but this is precipitated as such when the other sulphides are oxidized by boiling with sodium peroxide.

The presence of tin is confirmed by dissolving the stannic hydroxide in concentrated hydrochloric acid, reducing to stannous chloride by boiling with metallic iron, and testing with mercuric chloride, or also with hydrogen sulphide.

To detect antimony and arsenic it is recommended to acidify the filtrate from the stannic hydroxide, to warm until oxygen ceases to be evolved, then to cool and pass in a rapid stream of hydrogen sulphide. This treatment precipitates antimonic sulphide, which is filtered off. The resulting filtrate is then treated with a few drops of sodium thiosulphate solution and warmed until a precipitate begins to form. This may be sulphur alone, or also arsenious sulphide. The precipitation of arsenic is then made or completed by passing hydrogen sulphide.—*Jour. Chem. Soc.*, lxxiii, 184. H. L. W.

2. *Arsenic Pentachloride.*—Although phosphorus and antimony pentachlorides are well known, all the numerous attempts to prepare the pentachloride of arsenic have failed heretofore. The apparent non-existence of this compound is considered remarkable on account of the intermediate position of arsenic in its relations to phosphorus and antimony. Baskerville and Bennett now believe that they have succeeded in preparing this much-sought compound. They placed arsenic trichloride in a test-tube surrounded by solid carbon dioxide, then led in chlorine. The trichloride, which had solidified at the low temperature used, assumed a greenish yellow color and became liquid, and the liquid increased in bulk, since the chlorine was liquefied. By allowing "the excess" of chlorine to distil off at a temperature two or three degrees above the boiling point of chlorine ($-33{\cdot}6°$), a residual liquid was obtained, in one case at least, which had a

composition approaching that required for the supposed compound $AsCl_5$. It may be observed that there is very slight evidence here that the liquid was a definite compound rather than a solution of $AsCl_3$ in liquid chlorine, for there is no doubt that the boiling point of chlorine would be raised appreciably by the presence of a large amount of a substance in solution. However, the authors state that the product after being dissolved in absolute ether at $-30°$, gave yellow prisms when the solution was chilled several degrees, and that a special preparation made in a sealed tube formed beautiful yellow crystals at -38 or $40°$. These facts furnish, perhaps, some evidence of the existence of the pentachloride, but it seems unfortunate that the crystals were not analyzed.—*Jour. Amer. Chem. Soc.*, Nov., 1902. H. L. W.

3. *Electrolytic Peroxides of Lead, Nickel and Bismuth.*—HOLLARD finds that when lead is deposited in the form of a higher oxide by the electrolysis of nitric acid solutions of lead nitrate, the deposit does not consist of pure lead dioxide as has been supposed, but that it contains less lead than the amount corresponding to this compound (which contains 86·6 per cent of lead). The variation is but slight with large deposits, such as one containing 10^g of lead, but it is much greater with small quantities. When about $·01^g$ of lead was present, the deposit contained 74 per cent of lead, and as the lead was increased in quantity the amount of lead in the deposit gradually increased to 86·1 per cent for 10^g. The explanation is advanced that higher oxides than PbO_2 are formed, but this point does not appear to be proven.

A deposit of nickel oxide was obtained by electrolyzing an alkaline pyrophosphate solution containing chromic acid. The weight of the deposit corresponded to the formula NiO_4 on the assumption that nothing but nickel and oxygen was present, but in this case also the point was not proven. An anodic deposit from bismuth sulphate in nitric acid indicated the improbable formula Bi_2O_7.—*Comptes Rendus*, cxxxvi, 229. H. L. W.

4. *A Peculiar Double Salt of Silver Iodide.*—STRÖMHOLM has observed the remarkable fact that when solutions of tetraëthyl-ammonium iodide are treated with silver salts, the precipitates are not yellow but white. This is caused by the formation of a double salt $N(C_2H_5)_4I·2AgI$, which is distinguished from all the previously known double salts of the silver halides, not only by representing a new type, but by its great stability in dilute solutions. Such double salts are usually stable only in contact with very concentrated solutions of the soluble halides, hence the tetraethyl-ammonium-silver iodide resembles the double cyanides in its stability, although, unlike them, it is insoluble. The compound under consideration can be washed with a 1½ per cent solution of $N(C_2H_5)_4I$, but it is decomposed in contact with boiling water with formation of yellow silver iodide. It is decomposed also by warming with an excess of silver nitrate solution, with the formation of the same yellow product. The double salt is entirely stable when exposed to daylight.—*Berichte*, xxxvi, 142.

H. L. W.

5. *Method for the Determination of Carbon in Steel.*—As a solvent for steel when carbon is to be determined, G. W. SARGENT recommends the use of potassium ferric chloride, since it has the advantage of being less strongly colored than the usual reagent, potassium cupric chloride. A solution containing 267^g of commercial, chemically pure ferric chloride and $130{\cdot}7^g$ of potassium chloride in a liter is equivalent to the cupric solution commonly used. It should contain 1^{cc} of free hydrochloric acid in 225^{cc} in order to prevent the formation of basic ferric salts, but a greater quantity of acid than this is liable to cause the evolution of hydrogen and hydrocarbons. The reaction corresponds to the equation,

$$2FeCl_3 + Fe = 3FeCl_2.$$

The liquid which has been used can be brought to its original condition by chlorinating and adding the proper amount of potassium chloride.—*Jour. Amer. Chem. Soc.*, xxiv, 1076. H. L. W.

6. *Physical Chemistry for Physicians and Biologists;* by Dr. ERNST COHEN. Authorized Translation by MARTIN H. FISCHER, M.D. 8vo, pp. 343. New York, 1903. Henry Holt and Company.—This book is made up of fifteen lectures by a physical chemist, which serve as a satisfactory introduction to the subject in general, and which deal especially with the application of this science to medical and biological problems. The topics discussed are well chosen, the explanations are clear and satisfactory, and it is believed that the book will be very interesting and useful to those for whom it is intended. H. L. W.

7. *The Bunsen Flame of Radium.*—F. Giesel has shown that a very small amount of radium bromide gives a characteristic color to the Bunsen flame. He describes the spectrum as one consisting of two red bands and a bright blue line. He also saw feeble lines in the violet. C. RUNGE and J. PRECHT have investigated this spectrum with the aid of a Rowland grating of one meter radius. They found the spectral lines very transitory. The line in the blue at wave length 4826 remained the longest. It seemed of the same character as the barium line 5536; the strontium line 4607, and the calcium line 4226. A table of wave lengths is appended to their article.—*Ann. der Physik*, No. 3, 1903, pp. 655–657. J. T.

8. *Interference of Light by means of a Plane-parallel Plate.*—O. LUMMER and E. GEHRCKE discuss the various methods in interference spectroscopy and describe a method which resembles Michelson's echelon spectroscope; but which the authors think is simpler. It consists in the use of only one plane parallel plate. The method shows that many lines considered as consisting of a few components are far more complicated than has generally been supposed. The authors remark that Michelson's value for the red cadmium line $\lambda = 643{,}847$ cannot be considered a definite wave length measured to the given decimal place; nor a certain mean wave length of a continuous region; it is rather the center of gravity, so to speak, of a complicated system of

lines. The authors indicate that the varying results of different observers result from the use of different methods of observation rather than from the deficiencies of the apparatus.—*Ann. der Physik*, No. 3, 1903, pp. 457–478. J. T.

9. *Electricity carried by a Gaseous Ion.*—Prof. J. J. THOMSON has repeated his determination of this quantity by means of radium and more accurate apparatus. The number $3{\cdot}4 \times 10^{-10}$ was found as the charge in electrostatic units of the gaseous ion. This is about half the number $6{\cdot}5 \times 10^{-10}$ found in the author's previous experiments. The author attributes the difference to the failure of the first experiments to catch the positive atoms, thus making the value of n, the number of ions per c.c., little more than half the true value, while it made the value of e, the charge in electrostatic measure on an ion, twice as great as it ought to have been.—*Phil. Mag.*, March, 1903, pp. 346–365. J. T.

10. *Potential Distribution in the dark Cathode Space.*—A. WEHNELT finds that there are no potential maxima or minima in this space. The results, therefore, of W. P. Graham arise from faults of method of investigation. The author finds that Prof. Shuster's interpolation formula representing the run of potential is not confirmed by his investigation.—*Ann. der Physik*, No. 3, 1903, pp. 542–580. J. T.

11. *Mechanics, Molecular Physics and Heat;* by R. A. MILLIKAN. 242 pp. (Chicago: Scott, Foresman and Co.)—This is a treatise adapted to a twelve weeks' college course, in which the author has endeavored to combine a class-room text and laboratory manual. A certain number of well chosen laboratory exercises are made the basis of the course, whose object is to teach thoroughly a few fundamental principles rather than to present a large mass of facts. The theoretical discussions are generally sharp and clear and are followed by directions for the laboratory exercises, with illustrative problems. Another volume, for the second third of the year, covering the subjects of Electricity, Light and Sound, is to follow. This plan necessitates, for the third part of the year, a course of demonstration lectures on such parts of the subject as are more suitable to lecture than to laboratory presentation. D. A. K.

12. *American Physical Society.*—The American Physical Society is now joined with the Institution of Electrical Engineers and the Physical Society of London in the direction of the publication of "Science Abstracts" (edited by G. W. de Tunzelmann, London), and has elected Professor E. H. Hall of Harvard University as its representative on the publishing committee. In consequence of this arrangement, "abstracts" dealing with physics will in future be received by all members of the American Physical Society.

13. *The A B C of Photo-Micrography;* by W. H. WALMSLEY, 155 pp., 29 photo-micrographs. New York: Tennant & Ward.—Mr. Walmsley is a recognized authority in the photomicrographic world and his little manual is a welcome addition to the scientist's outfit. The subject is treated plainly yet thoroughly and comprehensively.

II. Geology and Natural History.

1. *United States Geological Survey.*—The following publications have recently been received:

Twenty-Second Annual Report, 1900–1. Pt. IV. Hydrography. 669 pp. 65 pls., 244 figs.—Mr. Newell, chief of the Division of Hydrography, reports on the progress of stream measurements throughout the United States (pp. 9–506). A. P. Davis's paper on the Hydrography of the American Isthmus presents the facts regarding the physiography, rainfall, drainage, etc, along the lines of the Nicaragua and Panama canals. The High Plains and their Utilization (pp. 637–667), by Willard D. Johnson, is the conclusion of a valuable contribution to physiography begun in the twenty-first annual report.

Masontown-Uniontown Folio, Pennsylvania, No. 82; by M. R. Campbell. 21 pp. with maps and sections.—The first of a series of new maps of the Pittsburg Coal District shows marked improvement over previous work. It is probably the most accurate piece of geologic mapping yet published. The economic geology includes coal, oil and clays; the well-known abandoned channels of this region are explained as consequences of local ice dams.

Ditney Folio, Indiana, No. 84; by M. L. Fuller and G. H. Ashley. 8 pp. with maps and sections.—The Ditney area is part of the Illinois-Indiana coal basin. It is a region of horizontal rocks moderately dissected and glaciated.

Ellensburg Folio, No. 86; by Geo. Otis Smith (Washington, D. C., 1903, 7 pp. text).—The area described geologically in this folio consists mainly of basaltic outflows of Neocene age which cover the older rocks. These have been in part eroded and upon them have been laid down gravels, fluviatile deposits, alluvium, etc. of Neocene and Pleistocene time, with andesitic outflows of the latter period. The mapping is an excellent piece of careful work and the descriptive text is clear and readable. In the field work Dr. Smith was assisted by Mr. F. C. Calkins.

L. V. P.

Bulletin No. 200. Reconnaissance of the Borax Deposits of Death Valley and Mohave Desert; by M. R. Campbell. 22 pp., 1 map.—The borax of the Death Valley region occurs in a regular stratum interbedded with semi-indurated sands and clays. The mines at Borate are the chief producers of borax and boracic acid in the United States.

Bulletin No. 201. Results of Primary Triangulation and Primary Traverse (1901–02); by Messrs. Wilson, Renshawe, Douglas and Goode.

Bulletin No. 202. Gold and Silver in Shales from Western Kansas; by Waldemar Lindgren. 19 pp.—In spite of published accounts to the contrary, Dr. Lindgren shows that the Kansas shales do not contain gold or silver in paying quantities.

Bulletin No 204. Fossil Flora of the John Day Basin,

Oregon; by Frank Hall Knowlton. 113 pp., xvii plates.—The fossil flora of the John Day Basin comprises 150 forms, distributed among 37 natural families and the anomalous group of Phyllites. Of the 150 forms, 24 are not specifically named, and 44 species and 1 variety are described as new. The previously known species number 81. These plants are from several different horizons, the oldest being regarded as of Lower Eocene, and the youngest of Upper Miocene age. It is concluded that the conditions which prevailed in the John Day Basin area during Tertiary times extended also into central Washington, northwestern Idahó, and western Oregon, and that the flora was distinctly a hard wood one containing many oaks, willows and maples, as in much of the area east of the Mississippi River at the present time. Many of the John Day species are closely related to forms now living in the Eastern States. A rather large-leaved *Gingko* appears to have been present in the uppermost beds. Very few ferns are present.

The writer does not attempt any special consideration of the comparative climatic conditions in the great Tertiary lake basins on the eastern flanks of the Rockies. They may in my opinion have been somewhat or even markedly warmer than the western slopes, especially in Eocene times, though not of course in the later Tertiary. G. R. W.

Division of Hydrology. — A Division of Hydrology has recently been organized in the hydrographic branch of the United States Geological Survey. The work of this division will include the gathering and filing of well records of all kinds, the study of artesian and other problems relating to underground waters, and the investigation of the stratigraphy of the water-bearing and associated rocks. In addition to the gathering of statistics relating to the flow, cost, etc., of the wells, it is hoped in the future to give especial attention to the geologic features which govern or which are related in any way to the supply of water.

The division will be sub-divided into two sections, the first embracing the Gulf and Mississippi River States and the States to the east, and the second embracing the remaining States and Territories. The charge of each section has been assigned to a geologist, the western section to Mr. N. H. Darton, and the eastern to Mr. M. L. Fuller. The office details are in charge of Mr. Fuller.

2. *Report of the State Geologist of Vermont for 1901–1902;* by George H. Perkins, State Geologist. 191 pp., 62 plates.—The first 30 pages of the report contains a brief account of the history of geological survey work in the State with reprints of articles first published elsewhere on Zadock Thompson and Augustus Wing, former state geologists. The body of the report contains papers by the State Geologist on mining industries and on the Geology of Grand Isle; by G. I. Finley on the Granite Area of Barre; by C. F. Richardson on the Terranes of

Orange County; and by H. W. Shimer on Petrographic Descriptions of the Dikes of Grand Isle. The paper on Grand Isle geology is a valuable contribution to the structural analysis of the Ordovician rocks of the region covered. The revival of the name Champlanian, for Lower Silurian or Ordovician, is unfortunate, especially in a paper in which Champlain clay is used seven times in another sense. H. S. W.

3. *A Report on the Geology of Louisiana*, Pt. VI; by GILBERT D. HARRIS, Geologist-in-charge, for the field seasons 1900–1901–1902. 288 pp., 10 plates, 7 figs. State Experiment Station, Baton-Rouge, La., Wm. C. Stubbs, Director.—The Report consists of a series of papers on various geological problems of the State: I. The Geology of the Mississippi Embayment, G. D. Harris. II. The Salines of North Louisiana. The geological age of the salt-bearing beds is Cretaceous for the salt-bearing rock of North Louisiana and Texas. III. The Geography and Geology of the Sabine River. The author has worked out a complete geological section for the region cut by the river. IV. Notes on the Geology along the Ouachita. Papers II, III, IV are by A. C. Veitch. V. Improvements in Louisiana Cartography; VI, Subterranean Waters of Louisiana; VII, Tides in the Rigolets, and VIII, Oil in Louisiana, by R. T. Harris. The horizon of this oil is not certainly fixed, though some of the wells issue from beds as late as Miocene. H. S. W.

4. *Tables of Minerals*; by S. L. PENFIELD. 77 pp. Sold by the Yale Coöperative Association, New Haven.—This pamphlet was issued to serve as a guide and reference book to accompany lectures on crystallography and descriptive mineralogy. The minerals are arranged in the tables as follows: I. According to the six systems of crystallization and their prominent subdivisions, the minerals of each subdivision being arranged in accordance with the chemical classification adopted by Dana. II. According to the elements, emphasis being given to minerals which are important from an economic standpoint. Short descriptions are added to the lists stating the uses of the minerals and brief summaries are given of the amount and value of their production. III. With reference to geological occurrence and association, as rock-making minerals, vein minerals, etc.

The minerals are given three ranks according to their relative importance, which is indicated in the tables by the type used in printing the names of the species. Accompanying the names of the minerals their chemical formulas are given and also numbers corresponding to the pages in Dana's Text-Book of Mineralogy and System of Mineralogy, on which descriptions of the species may be found. W. E. F.

5. *Ueber Urausscheidungen in rheinischen Basalten*; von F. ZIRKEL. (Bd. xxviii, Abh. mat. phys. Klasse d. K. Säch. Ges. d. Wiss., No. III, 1903, pp. 103–198.)—The basalts of the Rhine district have long been known for the many interesting inclusions which they contain, single minerals, such as olivine in masses,

sapphire crystals, etc. or aggregates of numbers of minerals associated together. These have been studied in great detail by Professor Zirkel, who presents in addition suggestive views regarding their origin and relation to igneous rocks. Since the appearance of the well-known work of LACROIX, this is without doubt the most important contribution to the literature of this subject. L. V. P.

6. *Princeton University Expedition to Patagonia.*—The first volume of the reports of this important expedition, issued in handsome quarto form with many plates under the J. Pierpont Morgan Publication fund, contains a narrative of the expeditions and an essay on the Geography of Southern Patagonia by J. B. HATCHER. The volume is dedicated to O. C. Marsh. The narrative gives an interesting account, though occasionally in over-elaborate phrasing, of three arduous journeys made by Hatcher and an assistant. Although much was discovered in the way of geological structure and although large collections of fossils were made, it is evident that a great amount of further study is needed in this little known region: the narrative must indeed prove inspiring to young men of good training and active habit. The physical features of the region are well described: the great shingle formation with which the plains are covered is explained as the littoral deposit of a retreating sea supplied with abundant boulders and cobbles from the glaciers and rivers of the Andes; the terraces of the plains are sea-cliffs carved during halts in the emergence of the land; the great transverse valleys were eroded by normal river action before the time of the depression in which the shingle formation was spread out, for they are blanketed with the shingle, and the terraces turn inland along the valley sides. The Straits of Magellan are explained as the southernmost of these transverse valleys, not yet fully emerged. The great piedmont lakes are accounted for by earth movements, little value being given to glacial erosion; and although extensive moraines are found east of the lakes, these deposits do not seem to be of great thickness. Two of the lakes, Viedma and Argentino, are drained by Santa Cruz river, the only large perennial river of the region. The other large lakes are discharged to the Pacific, through deep gorges in the Andes, for the most part unexplored. A chapter on the Tehuelche Indian tells of their abandoning the bow and arrow for the bolas since the introduction of horses by the Spaniards. W. M. D.

7. *Argentino-Chilian Boundary: Argentine Evidence.* Five 4to vols. (London, Clowes, 1900.)—The "brief" presented in five large volumes by the Argentine boundary commission under a title too long to be quoted, to the British Arbitration tribunal, whose decision has lately been rendered, deserves mention as an important contribution to Andean geography. It contains a large number of maps and many excellent photographs, besides an elaborate descriptive text, and must for many years serve as the standard general description of the region. Special attention

is naturally given to the contrast between the well defined lofty Andean chain, through which most of the eastern piedmont lakes are drained in deep canyons, and the indistinct continental divide on the plains east of the lakes, inasmuch as it was from the assumed coincidence of the divide and the mountain crest that the misunderstanding between Chile and Argentina arose.

W. M. D.

8. *The Bermuda Islands: Their Scenery, Climate, Productions, Physiography, Natural History, and Geology; with sketches of their Early History and the Changes Due to Man.* by ADDISON E. VERRILL. 558 pages, 8vo; 292 cuts in text; 40 plates. March, 1903.—This work is the author's reprint of part ii of vol. xi (centennial volume) of the Trans. Conn. Acad. of Arts and Sciences, with the addition of three pages of illustrations and a preface. It contains a comprehensive account of the islands, from personal observation and studies, which will be of great use both to casual visitors and to scientific students. The work is divided into forty-one chapters, besides various special subjects treated in the Addenda. It includes about equal parts of descriptive matter on physiography, including meteorology; history; botany; and zoology, chiefly relating to the land fauna. The climate, as related to the use of the islands as a health resort, receives considerable attention, as well as the history of former epidemics of imported diseases. The changes in the fauna and flora effected by man are very fully discussed, as well as the original flora and fauna. The insects of Bermuda have hitherto received very scant attention, only very meager lists of names, without descriptions or references to habits, having been given by writers. In this work the number of species is increased to 265, or more than double those previously recorded, and most of these are described and figured, especially those injurious to the crops. Attention is called to the remarkably small number of insects, and to the fact that nearly all have evidently been introduced by man since the settlement. Only three new species of insects are described: the large cicada (*C. Bermudiana* V.); a remarkable new genus of Psocids (*Heteropsocus dispar* V.), in which the male is fully winged, while the female has the hind wings abortive; and a geometrid moth (*Alcis Verrillata* Dyar). Chapters are also devoted to the whales, birds, sea-turtles, historical fishes, spiders, myriapods, terrestrial crustacea, earthworms, etc., but the marine invertebrates are mostly reserved for another volume.

The more interesting events in the early history and discovery of the islands are recorded, with quotations from the earliest visitors and settlers as to the original condition of the islands and the remarkable events of the early days. The history of the ancient ruined forts, situated on the deserted islands, is fully discussed, with illustrations of the ruins. The forty half-tone plates are excellent reproductions of photographs, most of which were made specially for this work by Mr. A. H. Verrill and other mem-

bers of Professor Verrill's parties. Many illustrate the more interesting views of scenery and peculiar rock-formations; others show unusual or interesting forms of vegetation. Perhaps the most remarkable are the reproductions of photographs (made from life) of the tropic-bird and other birds, and of various insects, including several butterflies, just in the act of taking their first flight after emerging from the pupa-cases on which they rest, and showing, at the same time, the larvæ feeding on their natural food-plants. One of the plates is an excellent likeness, with autograph, of the late Governor Lefroy, the only governor who has ever shown much interest in the natural history and archives of the islands, and who published several works on the botany and early history of the islands. In the Addenda, among other subjects, some of the early witchcraft trials are given. They were much like those of Salem, Mass., though about forty years earlier.

9. *Zoology of the Bermudas.* Vol. I, 427 pp., 8vo, 45 plates, many cuts. New Haven, Conn., March, 1903; by A. E. Verrill and associates.—This volume consists of reprints of fifteen principal articles, and some minor ones, relating to the zoölogy and geology of the Bermudas, which have been published during the past two years in the Trans. Conn. Acad. and elsewhere. They all relate to the collections made by the expeditions to the islands from Yale University, under the supervision of Professor Verrill. Among the subjects treated are the corals, actiniæ, annelids, echinoderms, mollusca, isopods, decapods, bryozoa, planarians, spiders, the cahow and other birds, etc. Most of these articles are freely illustrated and many new forms are described in several of them.

10. *West Indian Madreporarian Polyps*; by J. E. Duerden. 4to, 197 pp., 25 plates. Memoirs Nat. Acad. Sciences, VIII, 7th Mem.—Mr. Duerden, while residing several years in Jamaica, took good advantage of his opportunities to study the soft parts of a considerable variety of reef-corals that occur there. In these memoirs he gives numerous details concerning their anatomy and histology, well illustrated by numerous figures. This work adds greatly to our knowledge of the animals of the Madreporaria, as a whole, as well as to the particular forms studied, which include species of *Madrepora* (*Acropora*), *Porites*, *Siderastræa*, *Solenastræa*, *Orbicella*, *Cladocora*, *Manicina*, *Mæandrina* (*Mæandra*), *Favia*, *Isophyllia* (*Mussa*), *Oculina*, etc. An abstract of his results would be quite beyond the limits of a review at this time. It is, perhaps, unfortunate that the author has not adopted the revised nomenclature of the genera and species treated, but in general there can be no doubt about the identity of the species studied. However, it seems to me almost certain that his "*Agaricia fragilis*" is not the species that properly bears that name, which is always pedicellate, while his form is partially encrusting. A. E. V.

11. *The Coral Reefs of the Tropical Pacific*; by Alexander

AGASSIZ. Memoirs of the Mus. Comp. Zoology, Cambridge, Mass., vol. xxviii, iv, 4to, in five parts, 236 plates.—This extensive work is the result of the scientfic explorations carried on by Mr. Agassiz in the steamer Albatross, August, 1899, to March, 1900. The numerous illustrations are mostly heliotype reproductions of photographs made by members of the party. There are also numerous charts of the regions visited, and two colored plates of coral islands drawn by Mr. J. H. Emerton, from sketches by Mr. Agassiz and Dr. Mayer. The plates show very perfectly the character and structure of the very numerous reefs and islands visited, which include the Marquesas, Tuamotu, Society, Tonga, Fiji, Gilbert, Marshall, Caroline, and other groups of islands. Mr. Agassiz finds that there is far more diversity in the structure and modes of formation of these islands than Darwin, Dana, and other former writers supposed. In general, his observations do not sustain the current theories of the enormous thickness of the coral reefs, due to continuous upward growth during long periods of subsidence. This great work must long remain a standard treatise on the geology and physiography of the Pacific coral islands. A. E. V.

12. *Index Animalium;* by C. DAVIES SHERBORN. 1195 pp. Cambridge University Press. (New York: The Macmillan Company.)—'The objects of this work are (*a*) to provide zoologists with a complete list of all the generic and specific names that have been applied by authors to animals both fossil and recent since 1758; (*b*) to give an exact date for each page quotation; (*c*) to give a quotation for each reference sufficiently exact to be intelligible alike to the specialist and to the layman.' The present volume includes the years 1758–1800. Mr. Sherborn has shown remarkable patience and tireless effort in amassing the facts essential to such a book.

13. *Andrews's Botany all the Year Round;* by E. F. ANDREWS. 8vo, 302 pp. (American Book Company, New York, Cincinnati, and Chicago.)—This book is admirably adapted for botanical work in the average high school, and requires no expensive equipment. The lessons are so arranged that each subject is taken up at the time of year when the material for it is most abundant.

OBITUARY.

Rear-Admiral WILLIAM HARKNESS, U.S.N. (retired), the eminent astronomer, president of the American Association for the Advancement of Science in 1893, died on February 28, of typhoid fever, in his sixty-sixth year.

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[FOURTH SERIES.]

ART. XXXIV.—*The Apertures of Coronas, in Relation to the Number of Nuclei and their Size;* by C. BARUS.

1. *Introductory.*—Throughout my work with coronas, I have relied chiefly upon the color sequences, and have taken the data for numbers and sizes of cloud particles (a fixed degree of supersaturation presupposed) from the tables given elsewhere.* When apertures were measured this was done chiefly for the identification of the series to which the corona belongs. There is no doubt, however, that an expression for the diameters of particles in terms of the aperture of the coronas would be a great and immediate convenience, particularly as facility in using the color sequences is apt to be lost, unless one is at work with them continually. Apart from this the colors represent steps of progress, while the apertures should be continuously, even if irregularly, variable. The purpose is then to find under what conditions the discrepancies of aperture may be reduced to a minimum.

If the supersaturation is constant throughout, the diameters of cloud particles and their distance apart will in general be proportional quantities. Let m be the grams of water precipitated, n the number of particles per cubic centimeter, $D = n^{-1/3}$ their distance apart, d the diameter of each, s the aperture of the corona. If, therefore, for normal coronas $d = as$, where a is a constant found by purely optical experiments,

$$n = (6m/\pi a^3)s^3 = (6m/\pi)/d^3 = 1/D^3, \text{ and } d = D\,(\pi/6m)^{1/3}$$

But it is doubtful if these equations are true even for normal coronas, and they must certainly be a very crude approxima-

* This Journal (4), xiii, p. 81, 1902; Phil. Mag. (6), iv, p. 26, 1902; cf. Structure of the Nucleus, Smithsonian Contributions, 1902, chapter 3.

tion for coronas of the higher orders, where d and D are possibly both implicated in producing coronal effects. If one builds up a system of glass plates each sprinkled with lycopodium particles, the diffraction pattern which is finely annular for a single plate, is a mere blur for ten plates placed within a linear foot for instance, without changing the aperture appreciably. If the source of light and the eye are both distant, the coronas gradually lose sharpness and soon cease to be measurable as the number of plates increases. This indicates the nicety of distribution and the equality of diameter that must be met with in case of cloud particles, but it leaves the question open whether the distance apart of particles is not from the outset a consideration.

What is further menacing is the distortion produced by spherical and cylindrical vessels, the surfaces of which are rarely quite concentric. In my work with globes, I assumed that if the annuli showed no elliptic distortion and were small in aperture as compared with the aperture of the globe, distortion could be neglected. It is questionable, however, if this observation is vouched for, since the apertures of coronas are peculiarly sensitive to refraction, particularly when the distances of eye and source from the receiver are purposely chosen large. § 3.

Again, the quantity m is dependent on temperature to a marked degree. It is necessary, therefore, to refer coronas to a standard temperature as well as to a given degree of supersaturation, and the correction is particularly important if the coronas are to be used in estimating the number of particles. § 6.

Finally, the ratio of densities before and after exhaustion is a seriously difficult datum to determine, for it depends on the degree to which adiabatic conditions have been attained. It is here that the work is liable to be discrepant. Hence a determination of apertures has an ulterior value, for it is not improbable that the two series of results will *mutually interpret each other*. The present paper bears out this surmise. §7.

2. *Apparatus and preliminary results.*—The tables investigated contain a preliminary survey* of the sequence of coronas, their apertures (s) and the number of particles (n per cub. cm.) of specified diameter (d) encountered. The data for diameter and number, d and n, are taken from my work on successive exhaustion, where the experiments are largely non-optical, and they are compared with the corresponding data, d' and n', which follow from measurements of aperture. The eye and source of light are distant 1 and 3 meters, respectively, from the conden-

* The tables are withdrawn for brevity, since the data used in this paper are sufficiently given in the chart.

sation chamber between them. This was here a tall cylindrical vessel of as clear glass as possible, 50^{cm} long and 13^{cm} in diameter. The observations were made parallel to the axis, absence of distortion being assumed for the axial plane, an assumption which was here justified by a comparison with plate glass apparatus, though the latter was not quite large enough for the complete survey. The method of work was otherwise the same as that described in my earlier papers.

The constants of the goniometer were determined so that $s'd' = \cdot 0023$ and $n' = 120\,s'^3$ for the mean temperature 20° C. Phosphorus nuclei were used throughout. The pressure decrement on exhaustion was always $\delta p = 17^{cm}$.

The results of the tables are given in the accompanying chart, in which the old results for diameter and aperture, d and s, are laid off horizontally, the new results d' and s', computed as stated from the observed apertures, vertically. The discrepancy of the two sets of data is marked and the curves all show sustained periodicity.

3. *Diameter of cloud particle.*—The variations of d and d' are on the average $\delta d = 1\cdot 4\,\delta d'$ from curve 4, and $\delta d = 1\cdot 6\,\delta d'$ from curve 5. In other words, the diameters obtained for coronas by computation from the conditions of successive exhaustion are about 1·5 times larger than the same data estimated directly from the apertures of the coronas.

Moreover the new values of diameter, d', show a curious periodicity which must be peculiar to them, since the old values from the manner in which they were obtained (geometric progression) can not be periodic. There is accelerated increase of diameter toward the crimson types, Nos. 9 and 14, and a falling off which may even be a retrogression toward the green types, Nos. 4–5, 11–12, 15–16, these being respectively the crests and troughs of the wave. The undulation continues even beyond this, but it is then difficult to identify it when the annuli become crowded into the normal coronas. The results are similar in all the experiments. Moreover the same undulatory line was encountered both for phosphorus and for water nuclei, with maxima at the 9th and 14th coronas, when a different vessel (aspirator, 32^{cm} high, 22^{cm} in diameter) was used; and the ratio, $\delta d = 1\cdot 3\,\delta d'$, was distinctly smaller for this case, showing the marked influence of distortion due to the vessel. The same ratio (1·3) was found in connection with the preliminary experiments with plate glass apparatus (curve 3).

4. *Nucleation.*—Since nd^3 is constant, remarks of the same general character may be made for the nucleation, n, except that the discrepancy will be reciprocal in character and enormously exaggerated. If on the average $d = 1\cdot 5\,d'$, $n' = 3\cdot 4\,n$; if $d = 1\cdot 3\,d'$, $n' = 2\cdot 2\,n$, but the undulations have now become

so sweeping that a ratio can only be inferred for the small coronas.

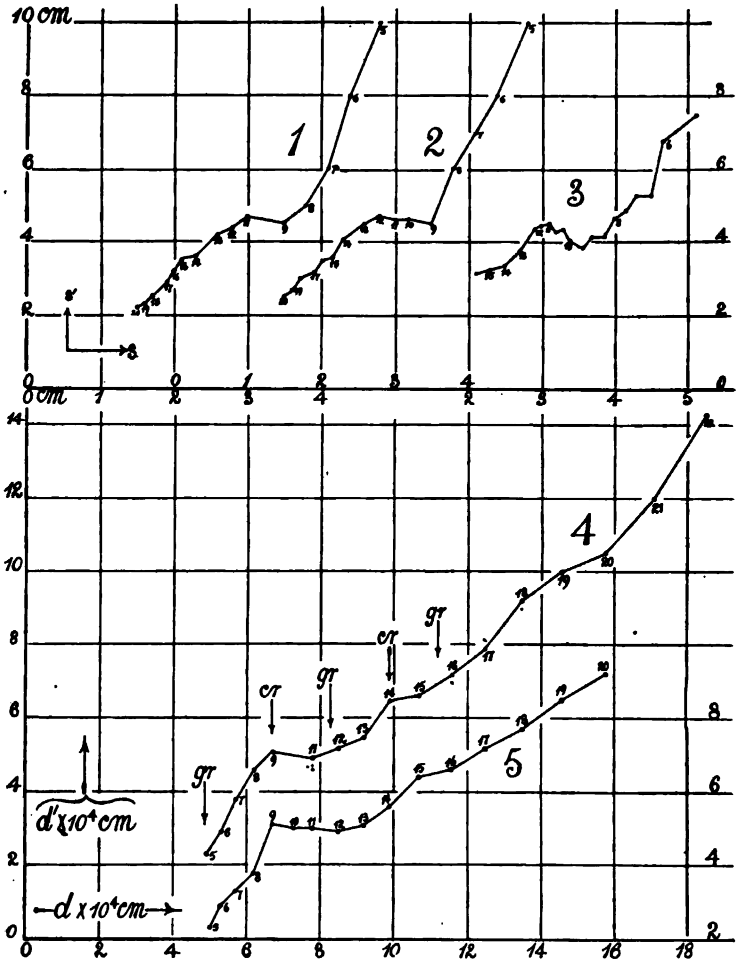


Chart.—Curves 1 and 2, relations of apertures computed from successive exhaustions (s) and directly measured (s'). Tall cylindrical receiver, 18[cm] in diameter. Curve 3, the same for plate glass apparatus 20[cm] deep. Coronas were difficult to place. Order numbers, z, attached to curves.

Curves 4 and 5, relation of diameter of fog particle computed from successive exhaustions (d), and from measurements of aperture (d'), both given in centimeters. Tall cylindrical receiver. The types of coronas are marked *gr* (green centered), *cr* (white-crimson centered). Curve 5 dropped ·0002[cm]. Small dots refer to a special series. Numbers on the curves show the orders (z) of the successive coronas.

5. *Cause of periodicity.*—If one inquires into the cause of the periodic discrepancies, it appears that the crimson coronas are too small or else the green coronas too large, for the data computed from exhaustions cannot be periodic. The former being white-centered with a diffuse red margin, it is impossible to mistake the outside edge of the first ring for the inside edge. The blue-green coronas, however, show a uniformly colored disc, and here the first ring may be of the same color as the disc and the corona would then be measured to the outside margin of the first ring. From this point of view only the crimson coronas are adapted for measurement, and both curves 4 and 5 would then give $d = 1{\cdot}3\ d'$ and $n' = 2{\cdot}2\ n$. Since the curves actually give evidence of diminishing aperture while the droplets certainly decrease in size, this explanation is plausible, though it does not agree well with the evidence from normal coronas. The red and crimson coronas are the only ones which retain the white center, and the phenomenon may in so far be regarded as similar to the case of normal coronas.

6. *Effect of temperature.*—The explanation of the discrepancy between d and d' (computed from exhaustions and measured from apertures, respectively) reduces in the most favorable case to $d = 1{\cdot}3\ d'$, and for this two explanations must be examined. Supposing that one does not inadvertently measure into a ring, the value of m which enters into the computation of d is very variable with temperature. For $\delta p = 17^{cm}$, for instance,

at 10°,	$m =$	$\cdot 42 \times 10^{-6}$ grams per cub. cm.,
20°,		$\cdot 76 \times 10^{-6}$ " " "
30°,		$1{\cdot}28 \times 10^{-6}$ " " "

Since d varies as $m^{-1/3}$, for the same nucleation, the values of d at 10°, 20°, 30°, will be in the ratio of ·75, ·96, 1·09, respectively, and the coronas will be in the same degree smaller. Between 20° and 30° this amounts to 2 per cent of the value at 20°. Hence to bring the values of d computed from successive exhaustion into coincidence with the data computed from apertures, would require a temperature excess of over 15°, which is out of the question.

7. *Pressure decrement.*—As none of the explanations are satisfactory, light of a different character may be thrown upon the discrepancy by computing the density ratio, y', of the gas after and before exhaustion, corresponding to the observed values, s'. Since if n is the nucleation, z the order of the corona in a geometric series, b the coefficient of time loss, t the time interval between exhaustions,

$$\log n = z\,(1 + bt) \log y$$

the equation corresponding to a different exhaustion ratio would be

$$\log n' = z(1+bt) \log y'$$

if the same corona, z, and time interval, t, is implied.

Hence $\delta(\log n) = \delta(\log y)$ while $n = (6m / \pi a^3)s^3 = 120s^3$. Therefore $\log y'/\log y = (\log A + 3 \log s')/(\log A + 3 \log s)$.

The computed values $s = a^3\sqrt{n\pi/6m}$ are given in the chart, curves 1, 2, 3. From the latter for $s = 5{\cdot}0$, $s' = 8{\cdot}0$ to $9{\cdot}0^{\text{cm}}$. Hence

$$s' = 8, \qquad y' = {\cdot}807,$$
$$s' = 9, \qquad y' = {\cdot}804,$$

whereas $y = {\cdot}819$ was the value computed in my work on coronas* for the exhaustion 76–58$^{\text{cm}}$.

Since roughly $y = (p/p_0)^{1/\gamma}$, where $p = 76$ and $\gamma = 1{\cdot}4$, the following values of δp obtain:

$s = 5{\cdot}0^{\text{cm}}$,	$\delta p = 18{\cdot}0^{\text{cm}}$,
$s' = 8{\cdot}0$	$19{\cdot}1$
$s' = 9{\cdot}0$	$19{\cdot}4$

Thus if the pressure decrement on exhaustion had been taken 1$^{\text{cm}}$ higher than the observed value, the apertures computed from successive exhaustions in the former memoir would agree with the average apertures directly measured in the present paper. Observationally this is out of the question, but it is nevertheless difficult to know just what pressure is effective in the adiabatically cooled receiver (cf. Structure of the Nucleus, p. 38, § 16), since neither the isothermal nor the adiabatic conditions will rigorously suffice. The memoir shows that isothermally $y = {\cdot}764$; adiabatically $y = {\cdot}825$; adiabatically with allowance for condensed water $y = {\cdot}819$, as already specified. The present aperture data demand $y = {\cdot}805$, which is even nearer to the isothermal y than the value taken.

Incidentally one may note the precision with which y must be entered or the pressure difference determined, if the observations are to be sufficiently close to admit of a computation of d and n. In other words, it is probable, that the ratio y may be determined with greater accuracy from the successive apertures as a whole, notwithstanding their periodic character, than by direct measurement. This is what I meant by stating that the two sets of observations would probably sustain each other, for nobody would be justified in using the apertures of abnormal coronas, unless such use was suggested and guided by independent evidence. My own conviction is that $n' = 2{\cdot}2\, n$ may now be accepted with confidence.

8. *Summary.*—The result of this paper is then favorable to the use of the apertures of coronas in place of the colors of the annuli, for estimating the number of particles corresponding to

* Structure of the Nucleus, chapters 3 and 4, this Journal, xiii, p. 83, 86.

a given degree of supersaturation at a given temperature. Full allowance must, however, be made for the occurrence of *periodic variations* of aperture in relation to the diameter of the fog particles; in other words, a given aperture is only of value when qualified by the type of corona (whether of the crimson or green order) to which the aperture belongs. Thus it will not in any case be possible to dispense completely with the color pattern. It is with the object of finding these corrections systematically that I have recently begun a series of experiments with a new form of plate glass apparatus and shall then refer to other developments. Homogeneous light, though in many respects desirable, gives effects so faint as to be useless in practice.

With the above data I am able to make an independent estimate of the number of particles in the saturated phosphorus emanation. The number found for the first fog of the series was (Phil. Mag. (6), iv, p. 25, 1902) $n = 83{,}000$; since $n' = 2{\cdot}2\,n$, $n' = 183{,}000$ particles per cub. cm. Now the density ratio before and after exhaustion is y, so that $1-y$ is the volume of saturated emanation added. As this has passed directly and slowly over excess of phosphorus, it must be very nearly saturated, becoming diluted on mixture with the dust free air of the receiver. Hence if n_0 particles per cub. cm. correspond to saturation, $n_0(1-y) = n' = 183{,}000$; or $n_0 = 10^6$. There must, therefore, be at least a million nuclei per cub. cm. of the air immediately in contact with a surface of phosphorus. The value following from my electrometer work was $n_0 = 2 \times 10^6$. The two methods are absolutely distinct but lead to data of the same order. It is because of the general reasonableness of the data which have followed from my simple hypothesis throughout a very wide territory of observation that I have felt bound to adhere to it, in spite of the more startling corpuscular explanations which might be adduced.

Brown University, Providence, R. I.

Art. XXXV.—*Klamath Mountain Section, California;* by J. S. Diller.

Introduction.

The purpose of this general review of the sedimentary rocks of the Klamath Mountains is to render more definite the geological horizons to which a large portion of them belong, and to give their general distribution and structural relations.

A preliminary geologic map of the Klamath Mountains was issued by the U. S. Geological Survey* in 1894, upon which all the rocks below the Cretaceous were grouped under one color. Fairbanks, Smith, Anderson and Hershey have since added much to the available knowledge of the region, but excepting part of Shasta County, where fossils are abundant, the geological age of the horizons has not been definitely determined.

Last summer, accompanied by Dr. T. W. Stanton and James Storrs, the author made a trip across the southern end of the Klamath Mountains to Mad River† and supplemented collections made by him in that region at various times during the last decade.

The formations of the Klamath Mountains for the most part trend northwesterly in approximately parallel belts from the northern end of the Sacramento Valley to the coast between the mouth of Red Wood Creek in California and Rogue River in Oregon. It is evident that the lines of deformation which determined the trend of outcrop follow the same course and are in the main approximately parallel to those of the Sierra Nevada. These belts along the western portion of the Klamath Mountains are quite regular, but nearer the mountain center they become very irregular owing to the presence of numerous masses of igneous rocks. Most of our attention was given to the sedimentary rocks, more or less fossiliferous, which may be grouped in the following categories: Pre-Devonian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous, Miocene, Pliocene and Pleistocene.

The pre-Devonian, Devonian and Carboniferons rocks with associated igneous masses form the bulk of the Klamath Mountains, and they occur in two belts which may be designated

* Fourteenth Annual Report, plate xlv.

† In this work the "Rough Geological Map of Trinity County," dated January 16, 1901, furnished in manuscript by Mr. Hershey, was found very useful. It gives a clear general idea of the areal distribution of important terranes. This map was noticed also in U. S. Geological Survey Bulletin 196, page 68. On page 9 of the same bulletin there is an outline map of the Klamath Mountains to which reference may be made for the relative position of localities mentioned in this paper.

the southwestern and northeastern. The southwestern belt embraces South Fork Mountain and all the country bordering the Salmon Mountains and Bully Choop upon the southwest, while the northeastern belt, beginning in the Bully Choop and Salmon Mountains, extends northeast to the Great Bend of Pit River. It is of importance to note that in each belt the oldest rocks lie upon the southwest, decreasing in age to the northeast, and in the northeastern belt the succession extends up through the Triassic, Jurassic and Cretaceous.

Pre-Devonian.

Southwestern belt of schists.—The oldest rocks of the region are schists,* of which the southwestern belt forms North Yallo Bally and South Fork Mountain and may be traced from the western part of Tehama County northwest between the South Fork of Trinity and Mad River to the coast at the mouth of Red Wood Creek, while the northeastern belt passes through Bully Choop and Salmon Mountains.

The principal rock of South Fork Mountain is a gray or greenish gray, more or less silky, mica-schist in which the mica is sericite. Although in well defined folia and fibers giving the mass a decided schistose structure, the mica is not well crystallized in distinct scales. The quartz is generally in excess of the mica and the mass is locally full of quartz veins. Another type of rock in this belt occurs in North Yallo Bally and locally along the lower portion of the southwestern slope of South Fork Mountain. The rock is greenish, generally more or less schistose, and composed chiefly of quartz and epidote. The occasional presence of blue hornblende in this rock suggests that it may be the result of contact metamorphism, but the field relations as far as known are not decisive.

The rocks bordering the schists of the South Fork Mountain upon both flanks are strongly contrasted with each other as well as with the schists. Upon the northeast are Devonian limestones, sandstones and shales cut by many igneous masses and decidedly metamorphosed. Upon the southwest between Mad River and the coast are conglomerates, sandstones and shales, at least in part of Cretaceous age. They are but little metamorphosed and are associated with comparatively few igneous rocks. The change from the schist to these rocks near Mad River is striking and indicates a profound break which may be most conveniently considered as the southwestern limit of the Klamath Mountains.

The general dip of the less altered sedimentary formations bordering the schists of South Fork Mountain belt upon both

* Included in the Abrams and Salmon formations of Hershey. Am. Geol., June, 1901, and manuscript map.

sides is to the northeastward and the fissile structure of the schists, although greatly crumpled, is for the most part in the same direction, suggesting that the quartz epidote schist upon the southwest side may be older than the sericite schist.

Northeastern belt of schists.—The northeastern belt of schists was seen only in the drainage of Salmon River and along Browns Creek near Douglass City on Trinity River. Although in general character the sericite schist of Brown Creek is like that of South Fork Mountain, its associations are quite different. On the west side it is limited by the belt of sediments containing the Hall City limestone, which is Carboniferous, and upon the east occurs a mass of schistose hornblende rocks apparently of igneous origin.

The South Fork Mountain belt of sericite schist is in general quite regular in outline and free from igneous masses, but the northeastern belt in Bully Choop and Salmon Mountains is much broken by a great variety of igneous intrusions.

DEVONIAN.

Southwestern Devonian belt.—In the southwestern belt there is a line of Devonian limestone lentils* which may be traced with many interruptions for over 100 miles parallel with the South Fork of Trinity River from its source to near Hoopa Valley, and throughout the whole distance the limestone rarely gets over a mile or two away from the contact with the schist of South Fork Mountain. It is probable that the same limestone occurs on the western slope of the Sacramento Valley at the Basin about 30 miles west of Red Bluff, where traces of crinoids, corals and other doubtful forms were found (1887) in one of a group of limestone ledges.

The first locality in this belt visited last summer was White Rock near the head of the South Fork of Trinity River, a few miles northwest of North Yallo Bally Mountain. The limestone is intimately associated with and broken by igneous rocks, some of which are vesicular as of surface flows. The caverned mass of limestone, which is scarcely an eighth of a mile in length, has tumbled down the slope, forming prominent cliffs and talus for nearly 1,000 feet. It is rather crystalline and the few fossils obtained were numbered 704.

Northwest from White Rock, within three-fourths of a mile, several small lenses of limestone crop out, and from one of these, only three feet in greatest extent, a number of shells and coiled forms were obtained and numbered 705. Concerning these fossils, Mr. Charles Schuchert of the U. S. National Museum at Washington, D. C., reports as follows:

* Judging from the earlier collections, this belt of limestone was doubtfully referred to the Jura-trias, U. S. Geol. Survey Bull. 196, p. 64.

"Loc. 705 has *Posidonomya* (very common) and two species of Ammonoids of the family *Prolecanitidæ*. Locality 704 (White Rock) has the same species of *Posidonomya* as that of 705 and with it is associated *Stromatopora* and other fossils too obscure to determine. The preservation of the ammonoids is such that one cannot make a certain determination of them, and yet their association with *Stromatopora* and *Posidonomya* seems to warrant the conclusion that the horizon of the limestone of 704 and 705 is in the Upper Devonian."

Associated with the small fossiliferous limestone, three-quarters of a mile west of White Rock, is a small mass of red chert with the usual round clear spots of murky silica, but no definite radiolarian structure could be found. Shales and sandstones are uncommon and much disturbed, but like the limestones generally strike northwest and dip northeast. These limestone lentils with others in the same strike occur within a few hundred feet of the mica schist of South Fork Mountain, and their outcrops were traced at intervals along this part of the South Fork of Trinity for over 10 miles.

Twenty miles further northwest we again examine the South Fork limestone belt beginning near the mouth of Rattlesnake Creek.

From Rattlesnake Creek near its mouth northwestward for several miles, there is a series of limestone lenses nearly in line and increasing in size northward to a point where it forms cliffs 100 feet in height. The outcrop has a length of about a quarter of a mile and a thickness of 50 feet. On the steep slope beneath the limestone cliff is a mass of basic igneous rock, part of which like a lava flow is full of cavities while other parts are volcanic conglomerate or tuff. In the conglomerate occur large and small fragments of slightly fossiliferous limestone (709a) like that of the main mass (709 and 710), as though the fragments were broken off during an eruption. The limestone mass itself is cut by an irregular body of the same igneous rock. The general strike of the limestone is parallel to the South Fork of Trinity, above which it rises 1,500 feet at a distance of over a mile. The rocks lying between the limestone and schist at this point are largely altered by igneous rocks and locally converted into hornfels.

The rocks exposed about the limestone ledges are almost wholly igneous of basic types related to gabbro and serpentine.

The same belt of limestone becomes prominent again about 20 miles further northwest in township 2 N., R. 7 E., on the summit of the divide west of Indian Creek. As at White Rock the sparsely fossiliferous limestone (711) is much broken up, covering acres of the gentler slope, and associated with it is

the same vesicular basaltic rock seen at so many other places. Upon the western side occur slaty siliceous rocks with spots suggesting organisms, but to the eastward on the Indian Creek slope igneous rocks abound.

Before following this line of limestones further northwest, it seems best to note several small masses which occur about eight miles northeast of the South Fork line but in approximately parallel position. One is on the divide between Prospect and Hay Fork creeks where fossils 703 and 706 were collected, and the other one and one-half miles southwest of Peanut where traces of fossils (707) were obtained.

Concerning the fossils from the last two localities as well as those near the mouth of Rattlesnake (709, 709a, 710) and 20 miles further northwestward 711, Mr. Schuchert reports as follows:

"Localities 703, 707, 709, 709a, 710 and 711 have in common one fauna in which the prevalent fossil is a coral of the genus *Chætetes.* I have had sections made of it and these I have shown to Mr. Ulrich, who said that this type of *Chætetes* is that of the Devonian and not of the Carboniferous. Associated with the *Chætetes* is a compound *Cyathophyllum*-like coral and a *Cladopora*, too much metamorphosed to be determined. At locality 709 there are two or three species of Stromatoporoids."

"While the limestone of these localities is greatly metamorphosed, yet the preservation allows the making out of the genera *Chætetes, Cladopora* and *Stromatopora.* This association is clearly indicative of the Devonian, and as the other California Devonian localities, excepting 704 and 705 already noted, are of middle Devonian time, it may be best to refer the above mentioned Klamath Mountain places to the same division."

"Loc. 706 is apparently of the same limestone belt as that of 709, but the fossils are too obscure to determine this with certainty."

Continuing northwestward from Rattlesnake Creek, the limestone crosses Butter Creek near its mouth and the South Fork of Trinity a few miles above Hyampom, and although it may occur at many points within the next 40 miles it was seen only at Three Forks Creek on the wagon road from Eureka to Hoopa Valley, where it yielded a few imperfect fossils among which Mr. Schuchert recognizes "A species of *Chætetes* and a *Cyathophyllum*-like coral common to nearly all the Devonian limestone outcrops along the South Fork."

Northeastern Devonian belt.—The northeastern belt of Devonian limestones and shales lies chiefly in the Sacramento drainage extending northward into the Klamath and Rogue River region. The southern part lying within the Redding Quadrangle, and as far north as Gazelle, has already received

much attention.* The principal limestone bodies rich in fossils occur near Klamath and on Hazel Creek. Smaller masses outcrop near Horsetown and at a number of points six, eight and eleven miles northeast of Redding, where they lie close to the Carboniferous in line with a larger mass two miles northwest of Baird.

One of the best sections of these rocks, but not including the whole Devonian series, may be obtained on Backbone Creek three and one-half miles north of Kennett, where nearly 900 feet of sediments are quite fully exposed.

1. Conglomerate	30 feet.	Many quartz pebbles and numerous holes from dissolved limestone fragments, some of which contain fossils like those of the limestones below. Unconformable on 2. Possibly Carboniferous.
2. Shales	140 "	Mostly dark with some thin sandy beds.
3. Limestone	100 "	Rather massive, and light colored, little chert but full of corals, etc. (6242).
4. Shales	300 "	Thin bedded sandstones and shales which are cherty and gray below. Near middle part is limestone lens 10 to 15 feet thick.
5. Limestone	250 "	Thin bedded and crowded with massive, branching and cup corals (6244). Cherty nodules and bands in bluish limestone becoming whitish and without chert below.
6. Siliceous shales	75 "	10 feet of banded chert at top with sandy shales, black shale and fine shaly sandstone, very thin bedded, resting on the igneous rocks below.

A large number of fossils were collected from the Devonian of the Redding Quadrangle, and these may in large part be referred to the section given although but few of the fossils were actually collected at the point where the section was measured. After enumerating a number of the species found at various localities, Mr. Schuchert concludes as follows:

* H. W. Fairbanks, Cal. State Mining Bureau, 11th Ann. Rept., 1893, pp. 47–49. Also Am. Geol., xiv, 30, 1894. J. S. Diller and Chas. Schuchert, this Journal (3), xlvii, 416, 1894. J. P. Smith, Jour. Geol., ii, 391, 1894. F. M. Anderson, Cal. State Mining Bureau Bull. No. 23, 1902, pp. 39–102.

"*Summary of the foregoing lists of fossils.*"

"The section of locality 6,242 given me by Mr. Diller, the thickness of which he estimates to be about 900 feet, has one general fauna indicative of the Middle Devonian. The general age has been known for some years, but the collections of 1902 have given us a definite section and also species that are known to occur in other American localities. This is especially true of the fossils of the Lower shale zone, which repeats the fauna of the Eureka and White Pine Districts of Nevada and the Middle Devonian of Iowa. The species that are common to at least two of these regions are *Schizaphoria striatula*, *Stropheodonta canace*, *Gypidula lotis*, *Pugnax altus*, *Atrypa missouriensis* and *Crytina missouriensis ?*"

"Taking these species in connection with the corals of the limestones, as *Heliolites porosa*, *Endophyllum* or *Spongophyllum* and *Phillipsastraea*, one sees plainly that the California Middle Devonian belongs to the 'Euro-Asiatic province'. This province extends east in North America as far as Central Missouri, Eastern Iowa, Milwaukee, Wisconsin, and Petosky, Michigan. East of these places occur the Middle Devonian faunas of the "North American type."

Continuing northward from the Kennett region the Devonian limestones and shales are well exposed, rich in fossils on Hazel Creek and Soda Creek, as well as near Gazelle, 20 miles northwest of Mount Shasta. Notes concerning all of these localities have been published, but there remains to call attention to a limestone three miles northeast of Kerby, in Oregon, which has furnished a few indistinct fossils. "A species of *Chætetes* and a *Cyathophyllum*-like coral," common to the Devonian limestone near South Fork have been recognized by Mr. Schuchert.

Carboniferous.

Southwestern Carboniferous belt.—This belt of limestone lenses and associated shales and sandstones lies some distance southwest of the schists of Bully Choop and Salmon Mountains and is bounded west by the Devonian belt of the South Fork of Trinity River. Small masses of limestones in this belt were first seen on the stage roads below Harrison gulch in Shasta County and found to extend northwest across the divide to the Hall City mines and beyond by the base of Chanchelulla to Hay Fork and Bridge Creek, where one of the lenses forms a remarkable natural bridge. From Hay Fork Valley the limestones extend up Baker and Big Creeks, and were not seen again until New River was reached near Patterson's Ranch.*

* U. S. Geol. Survey Bull. 196, p. 64.

The best section in this belt was obtained five miles north of Wildwood and one mile east of Hay Fork, where the limestone is yellowish gray and crystalline with. inconspicuous oolitic structure. The mass is less than a quarter of a mile in length and has a thickness of about 200 feet. Upon the southwest it is underlain by nearly 100 feet of reddish siliceous beds succeeded below by a great mass of basaltic rock which forms the bluffs along Hay Fork Creek. Upon the northeastern side the limestone is overlain by 100 feet of yellowish and reddish siliceous shales limited by the same sort of igneous rocks as that below. In the neighborhood of Harrison gulch there is much black shale, but its relation to the limestone was not determined. Associated with the Carboniferous, as also with the Devonian, there is an abundance of igneous rocks, especially of a basic type, and they occupy much larger areas than the sedimentary rocks.

Fossils were found at five localities in this belt of Carboniferous, and with many others from the northeastern belt were referred to Dr. George H. Girty, who reports the following forms from the Hall City locality (702):

Alga.
Amblysiphonella, two species.
Sponges, miscellaneous.
Zaphrentoid coral.
Fistulipora sp.
Rhombopora sp.
Stenopora? sp.
Miscellaneous Bryozoa.
Martinia?, two species.
Spirifer or Spiriferina.
Spirifer? sp., resembling Spirifer sulcifer Shumard.
Rhynchonella, resembling Uncinulus Theobaldi Waagen.
Camarophoria? sp., near S. superstes Verneuil.
Stacheoceras n. sp.
Gasteropod undet.

From the limestone five miles north of Wildwood and one mile east of Hay Fork Creek (701) Dr. Girty reports:

Alga.
Archæocidaris sp.
Crinoid stem.
Orthis sp.
Fusulina? sp.
Lithostrotion? sp.
Archæocidaris sp.
Crinoid stem.
Productus, cora type.
Martinia? sp.
Camarophoria? sp.
Enteletes? sp.
Orthis sp.
Squamularia Guadalupensis Shumard?
Seminula? sp.
Spirifer sp.

"One of the most common and at the same time peculiar fossils collected at this group of localities is a small pagodalike body whose exact affinities are very puzzling, but which I believe will prove to belong to the calcareous algae. Small concretionary forms, which appear to be inorganic, are also common. The fauna for the most part, however, is scanty

and obscure, not only because of the matrix, which is often considerably metamorphosed, but owing to the zoological relations of the forms present. Perhaps the most diagnostic fossil is an ammonite which was sent to Prof. J. P. Smith, who places it in the genus Stacheoceras, remarking:

'While Poponoceras in the broader sense ranges from Coal-measures to Middle Trias, the group of Stacheoceras has never been found outside of the Permian. It is therefore probable that the beds from which the Californian species was taken belong to the Permian. The species appears to be new, but resembles some form described by Gemmellaro from the Permian of Sicily.'

"Fusulina also has been somewhat questionably identified. It is impossible to doubt that this fauna is Carboniferous, and many indications point to its being late in the epoch. It is a remarkable fact that this fauna is related to those whose typical area is about Baird in only the most distant degree. It is quite unlike the faunas of either the Baird shales, the McCloud limestone, or the McCloud shale, so far as they are known; and it seems likely that its stratigraphic position must be above the McCloud shale. The apparent Permian age of this fauna, and the occurrence in it of a shell probably identical with *Squamularia Guadalupensis* Shumard and another resembling *Spirifer sulcifer* Shumard, suggest that it may belong to the fauna for which I recently proposed the regional name Guadalupian. In a general way the abundance of calci-sponges at Station 702 is evidence in the same direction, although it is undeniable that the common types constitute a small proportion of either fauna."

In the central part of the Klamath Mountains drained by the Salmon River there are a number of limestone ledges intimately associated with igneous rocks, but, as far as I am aware, fossils have not yet been found in them. To the eastward, in the drainage of Scott River about Scott Valley, a number of limestones occur. One near Oro Fino in Scott Valley and another near Parkers, on the mountain road from Gazelle to Callahans, containing pentagonal crinoid stems were formerly referred to the Juratrias, but as these fossils have been found in both the Carboniferous and Devonian limestones further south in the Klamath Mountains, the limestones in question may well be Paleozoic. This is rendered more probable by the occurrence of well-marked Devonian in the mountains west of Gazelle.

Northeastern Carboniferous belt.—The northeastern Carboniferous belt forms but a small part of the Klamath Mountains, being limited to the eastern projection beyond the Sacramento River in Shasta County. Although known for many years,

information concerning this belt has been greatly extended within the last decade by Fairbanks, Smith and Anderson in the publications already referred to.

The limestone where fully developed is the largest known in nothern California. It has a thickness of fully 2,000 feet and can be traced almost continuously along the McCloud River for nearly 50 miles. Before reaching the lavas of Mt. Shasta, however, it extends to the eastward, cropping out on the summit of Grizzly Peak, on the divide between the McCloud and Kosk Creek.

Beneath the McCloud limestone is a thick series of shales and sandstones with some conglomerates and occasional lenses of calcareous material. The sediments are often largely of volcanic matter, and include the "Baird shales" from which J. P. Smith* has described a large fauna. Above the McCloud limestone is a similar series in the McCloud shales of Smith but not so thick as the Baird formation, and grading upward into an extensive series of volcanic rocks.

Concerning the collections from the northeastern Carboniferous belt, Dr. Girty reports:

"A large part of the Carboniferous collections made in 1901 and 1902 were derived from horizons stratigraphically referable to the Baird shale, the McCloud limestone, and the McCloud shale, and from localities in the typical areas. The faunas of these beds have been listed long since by J. P. Smith,† and the more recent collections add little of material importance to the lists made at that time. It may be remarked, however, that recent collections made in the Carboniferous of Alaska are so suggestive of the fauna of the McCloud shale, by way of containing the same or similar species, as to indicate the extension of this fauna, and, possibly, of the earlier Carboniferous faunas of the California province, to this region."

The Bragdon formation, named by Hershey,‡ is here referred provisionally to the base of the Carboniferous sediments and require separate consideration. It is a mass of shales with thin-bedded sandstones and lenses of remarkable conglomerate, which is characterized chiefly by the silicious and calcareous pebbles it contains. The pebbles are generally less than an inch in diameter but, very rarely, are 12 inches through, and the majority of them are of cherty quartz. Those of limestone are occasionally fossiliferous and on the surface dissolve away, leaving holes in the conglomerate.

The distribution of the Bragdon formation is peculiar. Its eastern border lies east of the Sacramento, from Morleys to

* Jour. Geol., ii, pp. 593–602.
† Jour. Geol., ii, pp. 588–612, 1894.
‡ Am. Geol., xxvii, 236.

beyond Delta, and adjoins the Baird formation. To the westward it is limited in part by the Devonian near Kennett, but chiefly by the igneous rocks of Trinity and Salmon Mountains. To reach the latter it overlaps the Devonian limestones, shales and sandstones and covers them near the Sacramento between Backbone and Hazel Creek. Judging from its areal distribution and stratigraphic relations, it appears to belong to the lower portion of the Carboniferous section of that region.

Fossils were collected from the limestone pebbles at many points on both sides of the Sacramento. Although in a majority of cases the fossils are clearly in transported fragments derived from an older limestone in place, in other cases the same fossils are directly enclosed by the paste of the conglomerate without distinct evidence of such derivation. Concerning the fossils from the pebbles, Mr. Schuchert regards them as of Devonian age identical with those in the limestone of the Kennett region. He says "As to the age of the conglomerate I can only say that it is younger than the Middle Devonian."

The relation of the Bragdon formation upon the eastward to the Baird, appears to be that of conformable stratification, and Baird fossils have been found close to but not within the area assigned to the Bragdon formation. Conglomerates in the Baird formation contain the same fossils in pebbles and paste, especially when there is considerable igneous material. Similar tuffaceous conglomerates with fossiliferous limestone fragments occur at several horizons higher in the section.

The only fossils yet found in the Bragdon formation which certainly belong to its period of deposition, are some plant remains enclosed in light colored sandy shales a few miles west and northwest of Slatonis.

These specimens were all referred to Professor William M. Fontaine, who examined the material with great care, and fully recognizing the macerated condition of the specimens and their distortion after burial, remarked "that it is impossible to determine positively even their generic character." However, "All the imprints which show any recognizable features are strongly suggestive of Brachyphyllum." "Brachyphyllum is most developed in the Jurassic and lowest Cretaceous. If we may regard this plant as belonging to that genus, then, so far as its evidence goes, the strata are Jurassic or lowest Cretaceous. But as the generic place of the fossil can not be determined decidedly, and the amount of material is so small, the age can not be certainly fixed. A Jurassic age is indicated." With the conclusions of Professor Fontaine, Professor Lester F. Ward fully concurs.

Considering the importance of the imperfect fossils and

their determination by Professors Fontaine and Ward as doubtful, it seemed desirable to have them examined by other paleobotanists who worked in different fields. Accordingly Mr. David White, who is especially familiar with plants of the Carboniferous period, and Mr. F. H. Knowlton, whose studies are chiefly of upper Cretaceous and Tertiary forms, were asked to examine them.

Mr. White reports: "After carefully examining the Slatonis collections I can say but little except that the material is so fragmentary, so badly macerated, and so altered as not to justify any conclusions regarding its age." After fully describing all the plant fragments found in the specimens and weighing probabilities, Mr. White remarks:

"In brief, with the exceptions of the supposed cone fragments, I find nothing in the collection which is not entirely in accordance with an Upper Paleozoic date for the plants, while there is slight evidence, entitled to but very little weight, that the plants are of Upper Devonian or Lower Carboniferous age. The other plant material in hand is, however, of little weight to the contrary if the supposed cones are genuine, for, in the latter case, I believe the beds should be regarded as post-Paleozoic. Concerning the genineness of the cones I personally am somewhat in doubt."

Mr. Knowlton says: "I have given them a very careful study not only to-day but before this. In size and shape they do at first glance strongly suggest cones, but the more carefully they are looked at the less can I satisfy myself that they are cones. Mr. White has well described their appearance and it is not necessary for me to again go over the ground. There are a number of 'remains' on the rocks that have the same size and outline as the supposed cones, but a glance is sufficient to show that they are not such, and hence in the two or three examples that look most like cones I am inclined to regard them as also accidental. In any case I think it is perfectly safe to say that the material is too poorly preserved and fragmentary to base any important geological differentiation on, certainly as deciding whether the beds are Paleozoic or Mesozoic."

The geological age of the Bragdon formation is yet a matter of doubt. It is certainly younger than the Middle Devonian and probably belongs to the base of the Carboniferous section in that region, although it is absent in some places where it ought to appear. Largely on lithological evidence it has been referred by Hershey* to the Jurassic, and by Anderson† to the Triassic, but the fossils found thus far do not

* Am. Geol., xxvii, p. 236.

† Calif. State Mining Bureau, Copper Resources of Calif.—Geological Map of western part of Shasta County.

strongly support either view. The characteristic fossils common in the Pit formation (Triassic) of the same region, as well as the plant remains so well known in the Jurassic of Mariposa, California, and several localities in Oregon, were carefully sought for but not found in the Bragdon formation.

Triassic.

The part played by Triassic sediments in the structure of the Klamath Mountains is small, for they are known to occur with certainty only in Shasta County along Squaw Creek, between the McCloud River and the Great Bend of Pit River. The rocks of this age embrace the Pit formation, composed largely of shales associated with a smaller proportion of tuffs and conglomerates, and the Hosselkuss limestone 200 feet in thickness overlain by shales locally rich in *Monotis subcircularis*. The Triassic formations appear on Cedar Creek. Coming out from under the later lavas of the Lassen Peak region, they strike nearly southwest to the vicinity of Furnaceville, where they turn northerly, crossing Pit River, and then northeasterly about the head of Squaw Creek, where they are limited by the Carboniferous of Grizzly Peak, and disappear under the great lava field of northeastern California. Undoubtedly the Triassic formations once extended much further westward into the Klamath Mountains than now and have been removed by the great erosion of the Cretaceous and Tertiary periods.

Jurassic.

Jurassic strata like those of the Trias enter into the Klamath Mountains to a small extent only, and occur along the western arm of the Great Bend of Pit River, rich in fossils like those of the Taylorville region.* Shales and sandstones are common and occasional lenses of fossiliferous limestone occur in them. Conglomerates are not rare and usually contain much igneous material. Near the base they include interesting limestone fragments and nodules which are fossiliferous.

Cretaceous.

Cretaceous strata almost encircle the Klamath Mountains and a few isolated patches cling to their flanks, especially about the northern and southern ends, throwing an important light upon their history. Some of the outliers were noted in the preliminary map† and others have been discovered and published since.‡

* Geol. Soc. of Am., iii, pp. 369–412.
† U. S. Geol. Survey, Fourteenth Annual Report, pl. xlv.
‡ F. M. Anderson in the Jour. of Geol., x, pp. 144–159; also Proceedings of the California Academy of Sciences, Third Series, Geology, vol. ii, No. 1, 1902, and O. H. Hershey, this Journal, xlv, pp. 33–37.

It should be stated that in the supposed Cretaceous area on Post Creek near its junction with Rattlesnake some imperfect plant remnants were found last summer, concerning which Mr. Knowlton reports: "The best preserved specimen is a portion of a leaf apparently identical with that Fontaine has identified as *Angiopteridium strictinerve latifolium* in a forthcoming paper with Professor Ward on the flora of the Shasta group. This material would seem to be Cretaceous and to be similar in age to the Shasta."

The outliers at the southern end, as pointed out by Hershey, are aligned approximately northeast and southwest parallel to the Bully Choop Divide and the Cretaceous at its eastern base. The strike of the beds in the largest isolated area of Cretaceous, that of the Redding Creek basin, ranges generally between N. 55° to 71° E. and dips to the southeastward, indicating a line of deformation nearly perpendicular to that which determined the surface distribution of the rocks older than the Triassic.

Towards the northern end of the Klamath Mountains on the head of the Middle Fork of Smith River, and on the Illinois River near Waldo and Kerby, a mass of fossiliferous sandstones, conglomerates and shales occur resting with marked unconformity upon older rocks. Among the fossils, a number of which were new species, *Pecten operculiformis* and several other forms were determined. Concerning the collection as a whole Dr. Stanton reports: "There is a lack of well known characteristic species but the collection is probably from the Horsetown." The basal conglomerate near Waldo is composed almost wholly of sandstone fragments and not of peridotite or serpentine which are so abundant in that neighborhood, suggesting that as in other localities further to the northwest the peridotite was erupted after the Horsetown beds were deposited.

The greatest extent of this area is approximately northeast and southwest along the road from Waldo much of the way to Grant's Pass, and continuing in the same direction beyond Rogue River less than a score of miles over other rocks, brings one to the Graves Creek locality of Cretaceous sandstone and conglomerate so rich in fossils. The distribution of these two areas suggests that they occupy depressions in the same trough, which is in general parallel to a closely related line of outcropping Cretaceous extending from the vicinity of Riddles southwest across Rogue River to the coast near the mouth of Pistol River.

The general distribution of the Knoxville, Horsetown and Chico beds in the Klamath Mountain region is such as to confirm the conclusion long since drawn, that the Cretaceous

period was one of subsidence and the sea gradually transgressed until the Klamath Mountain region was almost if not completely covered by the sea. The remnants of the once extensive Cretaceous deposits on the flanks of the Klamath Mountains contain only open sea forms, and all were once continuous. Their present distribution is due to post-Cretaceous folding along axes running approximately northeast and southwest, or nearly perpendicular to the lines of older deformation which determine the distribution of the Paleozoic rocks in the Klamath Mountains. Anderson in his Physiography of the Klamath Mountains refers to two systems of folds and regards the northwest-southeast folds as the younger. It is possible, however, that a series of movements occurred along both systems at various times throughout their geologic history.

Eocene.

Eocene strata of marine origin touch the northern end of the Klamath Mountains on Rogue River at the mouth of the Illinois. They are chiefly sandstones with shales and conglomerates well characterized by various fossils and locally containing small masses of coal.

During the Eocene the Klamath Mountain region was a land area and only fresh water deposits could reasonably be expected within its borders and along its eastern base. In the vicinity of Ashland, Ore., sandstones and conglomerates occur containing fossil leaves which were once considered Miocene, but now that the beds of the John Day region have been thoroughly studied, the beds near Ashland are regarded by Mr. Knowlton as Eocene.* Some fossil leaves recently found in the Hay Fork beds according to Professor Knowlton appear to be Eocene. They will be noticed, however, in connection with associated strata of Miocene age.

Miocene.

The preliminary general geological map of the Klamath Mountain region† shows five areas of Miocene deposits, the largest of which is about Weaverville upon the southern border of the Klamath Mountains. Some notes were published concerning these deposits in the Fourteenth Annual, and later in Bulletin 196.‡

* U. S. Geol. Survey, Bulletin 204, p. 111, and letter dated Feb. 17, 1903.

† Plate xlv, Fourteenth Annual Report, U. S. Geological Survey.

‡ These deposits and others closely related have been discussed also by Mr. F. M. Anderson (The Physiographic Features of the Klamath Mountains, Jour. Geol., x, 144), and by O. H. Hershey (Neocene Deposits of the Klamath Region, California, Jour. Geol., x, 377).

In the Hay Fork region observations were extended last summer and a number of fossils collected which throw a stronger light upon the age of the deposits, and will help ultimately, when all the evidence is disclosed, to form a more complete picture of the conditions of deposition.

Hay Fork Valley has a length east and west of about 11 miles and a width of less than two miles. Looked at from the west, one is impressed with the contrasting slopes bounding the valley. The long gentle slope on the north side and the steep abrupt one on the south side suggest that the valley is largely the result of displacement. The fine shales and sandstones which fill the valley are well exposed on Hay Fork Creek below the mouth of Salt Creek, where they contain impure coaly layers and are locally full of shells of a fresh water gasteropod, and also of fruit and leaves. The light-colored beds have a thickness of several hundred feet and dip in various directions from 30 to 50 degrees, with strike in some places northeast and in others northwest.

The shells are very abundant throughout a thickness of nearly 100 feet and although not found with leaves in the same stratum were found within a few feet of leaves numbered 6170. The shells were referred to Dr. Dall, who reports as follows:

"The fossils consist of a single species of *Vivipara* very much crushed, and therefore hardly identifiable specifically. In a general way it is not unlike an undetermined species of '*Campelonia*' described and figured by Meek in the 40th Parallel Survey from Bear River, Utah, and referred with the other species from that horizon to the Cretaceous. There is no *Vivipara* known at present from California, either recent or fossil. I should say the species cannot be newer than the Pliocene and may be as old as the Cretaceous."

The fossil leaves collected from the Hay Fork beds were referred to Professor F. H. Knowlton, who reports as follows:

"No. 6164. Hay Fork Creek, 100 yards below the mouth of Salt Creek, three-quarters of a mile west of the town of Hay Fork.

"No. 6169. Tule Creek near its mouth into Hay Fork Creek, one and one-half mile west of town of Hay Fork.

This material is similar, being a fine-grained, soft and highly carbonaceous clay. It is filled with fruits of *Trapa*, of the type of the living *Trapa natans*, nothing else being present. The fruits are mostly broken, but a sufficient number are so preserved as to leave no doubt as to their nature. When the 'horns' are broken away from the body of the fruit they very much resemble small shark's teeth, and were so identified last year.* Trapa

* U. S. Geol. Survey, Bull. 196, p. 43. Report by Mr. F. A. Lucas.

is fresh water aquatic, growing in shallow water, its roots anchored in the mud and its numerous leaves forming a rosette on the surface of the water. It is difficult to understand how so many of the fruits could have been preserved without a trace of a leaf.

I have described two species of Trapa from the lake beds of the Payette formation of Boise County, Idaho, one of which (*T. occidentalis*), 18th Ann. Rept. U. S. G. S., Pt. III, pl. cii, fig. 7^b, is of the same type apparently as certain of the fruits from Trinity County, Cal. They are probably not identical, although so far as I can see the difference is mainly one of size.

"No. 6170. Hay Fork Creek, opposite Van Metres, two and one-quarter miles west of the town of Hay Fork.

This material is a soft, bluish or greenish clay and has the fossil plants well preserved. I find the following species:

Sequoia angustifolia Lesq.
Salix angusta? Al. Br.
Salix Californica Lesq.
Quercus convexa Lesq.
Quercus elænoides Lesq.
Ficus ungeri? Lesq.
Aralia whitneyi Lesq.

These are all more or less well known Auriferous Gravels species except *Ficus ungeri*, which is doubtfully identified here. It is normally a Green River species, and it will probably be found that the Hay Fork leaves are similar to but not quite identical with it. The identification of *Salix angusta* is also somewhat doubtful. That the flora we are here considering is similar in age to the Auriferous Gravels is clear, but in the light of more recent work it is perhaps desirable to attempt to fix, if possible, the part of the Auriferous Gravels they most resemble. Of the four species clearly identified, typically Auriferous Gravels (*Salix Californica*, *Quercus convexa*, *Quercus elænoides* and *Aralia whitneyi*), three are found at Table Mountain and one at Chalk Bluffs.

Turner is of the opinion that the Table Mountain locality is of later age than the Auriferous Gravels proper, while Lindgren regards it as pretty definitely settled that Chalk Bluffs is similar in age to Iowa Hill and Independence Hill, that is of the age of the bench gravels or lowest rhyolitic tuffs. He regards them as upper Miocene and I see no reason to question this.

From this meagre evidence it appears that the Trinity County leaves under consideration are most like those from Table Mountain, but this whole subject must await a thorough revision of the material and available data before any thoroughly satisfactory or reliable conclusions can be reached. I have a large amount of material from various localities and as soon as possible it is my intention to work it up with a view to fixing the horizons and whence it came, but until that is done I can hardly venture more

than to say that the Trinity leaves are similar in age to a part of what has been called the Auriferous Gravels.

"No. 6168. Hay Fork Creek, one and three-quarter miles west of town of Hay Fork. A considerable collection of material, the matrix being a soft sandstone.

The following are represented:

Juglans Schimperi Lesq.
Populus Heerii Lesq.
Rhamnus? sp.

The first species is present in great abundance and in perfectly typical examples, while the last (*Populus Heerii*) is so closely similar to the type that it might almost have been the original from which the figure was made. I state this for the purpose of showing that there can be no question as to their identification. These two species are found at Florissant, Colorado, and should be referred to the upper Eocene.

I think the material from this locality is probably the same as that which I reported on last year, referring it with hesitation to the upper Miocene. Only two species were present in that collection and both are of general distribution throughout the Tertiary. With the present collection the matter is different; the forms recognized are clearly older, and I am forced to the conclusion that there must be two horizons represented in the Hay Fork area."

The new points concerning the Hay Fork beds brought out by this collection are: (1) The determination of the supposed shark's teeth as fruit of a fresh water plant removes the chief argument tending to show that the Hay Fork beds were formed in an estuary near sea-level. (2) The Hay Fork beds are now not only more definitely correlated to the Auriferous Gravels but with a portion of them of upper Miocene age. (3) The recognition of Eocene forms is somewhat of a surprise. In the field all the beds in Hay Fork Valley were supposed to be of the same age. The layers containing the upper Miocene forms (6170) are from the west and lowest end of the valley and without intervening Eocene beds rest directly with marked unconformity on the adjacent Paleozoic rocks.

Pliocene.

Along the northern side of Hay Fork Valley there is a mass of white tuff at least 15 feet in thickness which is closely related to a similar deposit in the Redding Creek basin of the same region. These deposits are of but little importance as to size, but as a time-marker they may become important in correlating the sediments of independent basins. Considering the size of the deposit, its distribution and the general character of the material, its source is believed to be Lassens Peak,

from whose eruptions there is a great mass of tuff in the Sacramento Valley cropping out all along its western border from Gas Point to Thomas Creek. Lassen Peak is the nearest large volcano, and its known tuffs are separated from those of the basins referred to above by about 20 miles over a low mountain. With a view to determine certainly if possible the source of the material of the tuff, two chemical analyses were made by Dr. E. T. Allen. One specimen was from Rice's quarry, six miles southeast of Paskenta, representing the tuff of the Sacramento Valley; the other specimen is from the Redding Creek basin.

ANALYSES OF LASSEN PEAK LAVAS AND TUFFS.

	1	2	3	4	5	6	7	8
SiO_2	58·08	68·72	76·75	70·01	65·78	67·27	60·23	70·40
Al_2O_3	18·37	15·15	12·32	12·61	14·87	14·84	18·64	13·50
Fe_2O_3	2·92	1·16		1·47	1·27	1·01	3·81	1·31
FeO	3·38	1·76	1·36	·50	1·	·85	·88	1·61
MgO	3·35	1·28	none	·72	1·89	1·36	1·64	·37
CaO	7·05	3·30	1·18	1·06	2·41	2·30	6·04	·56
Na_2O	3·66	4·26	3·55	1·94	2·58	2·94	3·87	2·11
K_2O	1·33	2·78	3·98	5·12	2·71	2·87	1·46	2·39
H_2O-	1·09	·74	·54	2·37	2·87	1·55	·95	1·05
H_2O+	---	---	---	4·68	4·32	4·95	1·97	7·41
TiO_2	·44	·31	---	---	---	·27	·57	---
ZrO_2	---	---	---	---	---	none	·01	---
CO_2	---	---	---	---	---	none	none	
P_2O_5	·16	·09	---	·04	·08	·06	·20	·08
SO_3	---	---	---	---	---	none	none	
Cl	---	---	---	---	---	---	---	---
F	---	---	---	---	---	---	---	---
S	---	---	---	---	---	---	---	---
Cr_2O_3	none	none	---	---	---	trace	trace	---
NiO	---	---	---	---	---	---	---	---
MnO	·13	0·11	---	trace	trace	trace	trace	trace
BaO	·03	·07	---	---	---	·15	·11	---
SrO	·02	·03	---	---	---	none	·05	---
Li_2O	trace	trace	---	---	---	---	---	---
	100·01	99·76	99·68	100·52	99·78	100·38	100·43	100·79

1. Andesite. Old rim of Lassen Peak. Analyst, W. F. Hillebrand. 1887.
2. Dacite of last eruption at northwest base of Lassen Peak. Analyst, W. F. Hillebrand. 1887.
3. Glass base from dacite of Lassen Peak. Analyst, P. W. Shimer. 1883.
4. Tuff about 40 miles southeast of Lassen Peak. Analyst, George Steiger. 1893.

5. Tuff, 6 miles northeast of Paskenta, Tehama County, Cal. Analyst, George Steiger. 1893.
6. Another portion of same mass as 5. Analyst, E. T. Allen. 1903.
7. Tuff, Redding Creek Basin, Trinity County, Cal. Analyst, E. T. Allen. 1903.
8. Tuff, Hyampom, Trinity County, Cal. Analyst, George Steiger. 1893.

A number of chemical analyses of Lassen Peak lavas, including both andesites and dacites, were made some years ago and average examples are given in 1 and 2 of the accompanying table. The dacites have a glassy base which, as shown by analysis 3 is richer in silica and potash than the lava. The tuff 40 miles southeast of Lassen Peak (4) is supposed to have resulted from a late eruption of that peak and was put in for comparison with the tuff of the Sacramento Valley (5 and 6) from the same source, and afford a basis for comparison with that west of the Sacramento Valley on Redding Creek (7) and at Hyampom (8) in the Klamath Mountains. The last two are certainly not of the same eruption, for they are widely different in age. The tuff of Hyampom, so rich in particles of clear volcanic glass, contains Miocene leaves, while that of Redding Creek and Hay Fork basins is much later, overlying the Miocene shales, and of much more recent appearance. The leaf-bearing shales of Hay Fork have been found rich in infusoria and as far as seen, although like tuff in appearance, contain no particles of glass which could be identified with certainty.

Becker* called attention to much volcanic material in Lake County, and Hershey† suggested that the prevailing winds of that region being from the south the tuff in the Neocene basins of the Klamath Mountains may have come from Lake County.

As to the age of the tuffs in Hay Fork and Redding Creek basins, from the fact that they occur between the Pleistocene gravel and Miocene shales and sandstones they may be regarded in general as being Pliocene.

Pleistocene.

The Pleistocene of the Klamath Mountains embraces numerous elevated beaches along the coast as well as glacial and fluvial deposits among the mountains, but for our present purpose these have been sufficiently treated in U. S. Geological Survey Bulletin 196, page 24, and by Hershey in the Journal of Geology, volume viii, page 42.

* U. S. Geol. Survey Monograph xiii.
† Jour. Geol., x, 391.

Resumé.

The sedimentary rocks of the Klamath Mountains, excepting those which are pre-Devonian, belong to the following groups: Devonian, Carboniferous, Triassic, Jurassic, Cretaceous, Eocene, Miocene, Pliocene, and Pleistocene.

The general conclusions concerning their distribution and structural relations may be summarized as follows:

1. The Klamath Mountains, although composed in large part of igneous rocks, are made up chiefly of pre-Devonian schists with Devonian and Carboniferous sediments, among which fossiliferous limestones occur.

2. Triassic and Jurassic sediments form but a small part of the Klamath Mountains, occurring, as far as yet definitely known, only in the southeastern projection between the McCloud River and the Great Bend of Pit River.

3. The Cretaceous strata of marine origin practically surround the Klamath Mountains and occur also in separate basins within their northern and southern portions.

4. The Eocene, Miocene, Pliocene and Pleistocene sediments near the coast are of marine origin, but inland among the Klamath Mountains some, if not all, of the basins containing marine Cretaceous beds contain also fresh water Eocene, Miocene, Pliocene, and Pleistocene sediments.

5. The older sedimentary rocks, including those of Paleozoic or greater age, forming the bulk of the Klamath Mountains, are arranged in two belts running northwest from the end of the Sacramento Valley to the coast between Red Wood Creek in California and the mouth of Rogue River in Oregon.

6. The dividing line between the belts is occupied largely by igneous rocks. It lies near the southwestern base of the Bully Choop and Salmon Mountains.

7. Both belts embrace pre-Devonian, Devonian and Carboniferous sediments. The oldest rocks of each belt are upon the southwest side and decrease in age to the northeast. The prevailing dip of the strata throughout the greater part of the Klamath Mountains and the northern end of the Coast range is in the same direction.

8. This repetition of beds in the same order in the direction of the prevailing dip suggests faulting and that a great fault runs northwest and southeast near the southwest base of Bully Choop and Salmon Mountains.

9. West of the ancient schists of the South Fork Mountain, bordering the coast, lies the North Coast Range of California, composed of shales, sandstones and conglomerates which are at least in part Cretaceous and perhaps wholly of Mesozoic age.

10. Between these unaltered sediments and the pre-Devonian schists toward which they dip, there is a great break along the southwest line of South Fork Mountain marking the line between the Klamath Mountains and the Coast Range proper.

U. S. Geological Survey, Washington, D. C.

ART. XXXVI.—*Rotatory Polarization Mechanically Produced;* by ARTHUR W. EWELL.

SOME four years ago Prof. A. W. Wright of Yale University suggested to the author that he investigate the optical effects of torsion upon transparent media, citing a reference of Verdet* to the unsuccessful attempts of F. E. Neumann and Drion to obtain rotatory polarization by twisting. The results of the author's investigation were given in a paper † published a year later in which it was demonstrated that jelly in a rubber tube, when subjected to severe twist, rotates in the opposite direction to the twist, the plane of polarization of polarized light which traverses the jelly parallel to the axis of twist, and that this rotation is a higher power of the twist than the first. In a paper‡ published a year later it was shown that this rotatory polarization was quite uniform over the cross section of a jelly tube; that it was present in an annular jelly tube formed by pouring the jelly into the space between two rubber tubes both of which were cemented to glass caps; that a glass rod twisted when heated to softness showed no rotatory polarization when allowed to cool; and, finally, that glycerine, stirred or twisted in rubber tubes, even at zero degrees showed no rotatory polarization.

The present paper describes experiments performed during the past two years, in seeking definite quantitative relations between the rotation of the plane of polarization and the twist and twisting moment and what conditions besides the twist influence the rotation. A great number of experiments were make with several forms of apparatus which afterwards proved to be merely preliminary. Only the final form of apparatus and the experiments performed with it will be described.

MATERIAL USED.

Jelly.—The great majority of the experiments were made with jelly, which is by far the best material which the author has discovered, since it may be made very transparent, possesses in a marked degree all the features of an elastic solid and allows great distortion without serious injury to its optical or mechanical properties.

In the experiments described in former papers the jelly was composed of choice calves foot gelatine and water. The jelly used in the experiments described in this paper contained in addition glycerine, which makes the jelly tougher and constant,

* Verdet: Optique ii, p. 389.

† This Journal (3), viii, 89, 1899; also abstract in Phys. Zeitschrift, i, No. 18.

‡ Johns Hopkins University Circulars, June, 1900.

neither drying up nor putrefying. The proportion most suitable for the majority of the experiments was 1^g gelatine, 5^{cc} water, 5^{cc} glycerine in warm weather, and in winter a little more glycerine and water. A greater proportion of glycerine to water makes a slimy jelly, less of the nature of a rigid, hard body. The stiffest jelly which is still sufficiently transparent consists of 1^g gelatine, $2\frac{1}{2}^{cc}$ water, $2\frac{1}{2}^{cc}$ glycerine. The mixture of gelatine, water and glycerine was heated at about 100° C. until the gelatine was completely dissolved, which usually required nearly an hour.

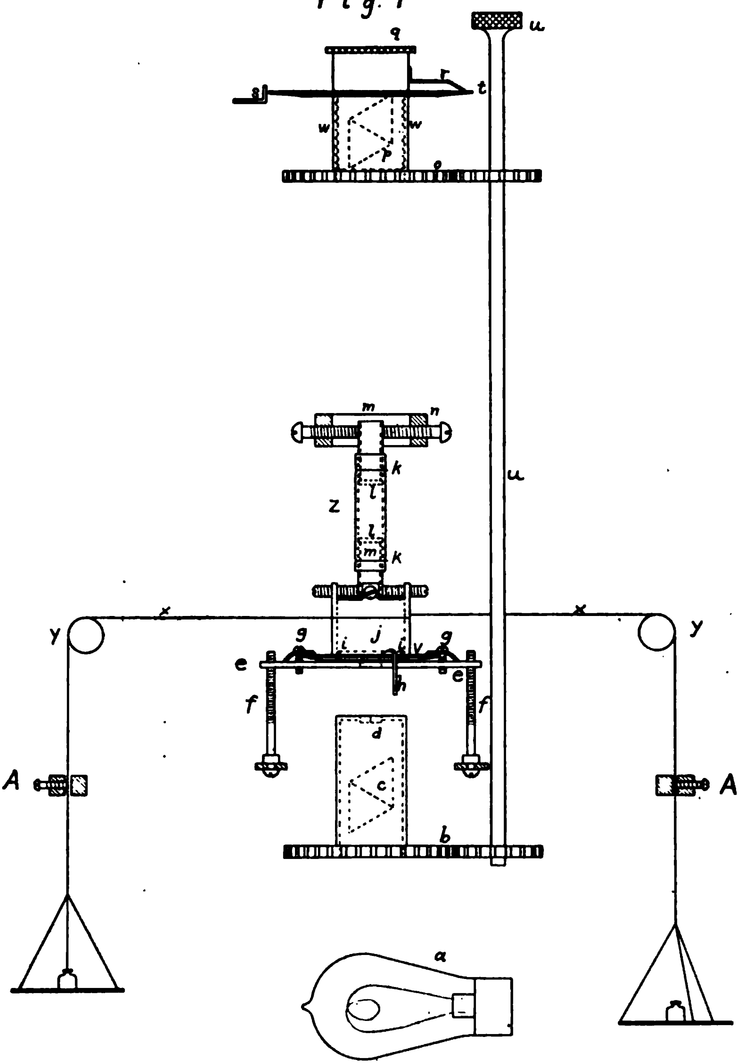
Jelly Tubes.—Most of the experiments described below were performed with jelly in rubber tubes. A different form of tube was used from that of the earlier papers. A proper length of proper sized *pure* rubber tubing was chosen and a brass tube about 3^{cm} long, the external diameter of which was slightly larger than the internal diameter of the rubber tube, was slipped into each end of the rubber tube for about 1^{cm}, a circular glass disk slightly larger than the brass tube being pushed in ahead of the brass tube. The tube was then completely filled with the melted jelly through a slit in the side. With patient manipulation air bubbles could be avoided. The glycerine jelly was so tough that it was not necessary to close the slit with wax. The rubber tube was bound upon the brass tube with wire; unless otherwise stated, the internal diameter of the rubber tube was $1{\cdot}14^{cm}$ and the external diameter of the brass tube $1{\cdot}42^{cm}$. This style of jelly tube, which will henceforth be designated as a "jelly tube," is greatly superior to the former style where square glass plates were directly cemented to the rubber tube, in that the brass tube could be grasped with far less distortion of the tube and afforded far more opportunity for adjustment than the glass plates.

Independent Jelly Cylinders.—These were constructed by pouring melted jelly into a test tube, allowing the jelly to set, then plunging the test tube into hot water which melted the jelly next the glass, allowing the cylindrical core to slip out. A suitable length was cut off with a sharp knife; short lengths of slightly smaller rubber tubing (internal diameter $1{\cdot}76^{cm}$) were slipped over the ends for about 7^{mm}. A glass disk was placed against each end inside the rubber tubing and a brass tube slightly larger than the rubber tubing (external diameter 1·90) was then pushed into the rubber tube up to the glass disk. The brass tubes were grasped in the clamps by which the twist was applied. These independent jelly cylinders were similar to what the jelly tubes would be with the central part of the rubber tube cut away. The jelly cylinder must be of exactly the popular diameter. If too large the rubber tubing is quite likely to cut it and if too small it is likely to slip in the rubber tubes.

APPARATUS.

The general apparatus in its final form is illustrated in outline in fig. 1. It is a biquartz polarimeter, without lenses and

Fig. 1



with certain attachments for this particular work. The light passes from the frosted incandescent lamp, *a*, through the first Nicol, *c*, the biquartz, *d*, the jelly tube, *z*, and the second Nicol,

p, where it enters the observer's eye. The upper Nicol, *p*, is mounted in the tube, *q*, which rotates freely within the tube, *w*, attached to the gear wheel, *o*, and a graduated circle, *t*. The position of this Nicol is read with a pointer, *v*. The lower Nicol, *c*, and the biquartz, *d*, are fixed in a tube which is attached to the gear wheel, *b*. The upper gear wheel, *o*, and graduated circle, *t*, can be rotated in step with the lower gear wheel, *b*, the lower Nicol, *c*, and biquartz, *d*, by means of the rod, *u*, with its small attached gears. Thus the azimuth of polarization of the entering light, with reference to any particular radius of the jelly tube, may be varied without changing the relative position of the lower Nicol and the graduated circle of the analyzer. The circle, *t*, has a second graduation along the outer edge and the azimuth is read by means of the index, *s*. *z* represents a jelly tube of the form described above, *m* is the brass tube, *e* the glass disk and *k* the binding wire. The upper brass tube is clamped in the fixed clamp, *n* (the position of this clamp can be varied to suit different lengths of tube). The lower brass tube is fastened in the movable clamp, *j*. A graduated circle, *v*, is attached to the bottom of this clamp and the amount of twist applied to the tube is read with the index, *h*. The twist was generally produced by pulling the cords, *x*, by weights, or by hand, and then clamping the cords at A. The pulleys, *y*, had cone-bearings and turned with no appreciable friction. Their position could readily be varied. The lower clamp could be clamped in position by the clips, *g*, to the platform, *e*, which could be raised or lowered by the screws, *f*. *i* represents the cross section of a ring soldered to the platform, *e*, which fitted loosely within the lower clamp and served to keep it from being drawn too far to one side during adjustments.

Signs.—The right-handed screw notation is adopted.* If, advancing in any direction, the direction of rotation of the plane of polarization or the direction of twist of the body be related to the direction of advance as the direction of rotation of a right-handed screw is related to its advance, the rotation or twist is said to be positive while the opposite twist or rotation is called negative. The graduated circles being numbered in the usual direction, an increase in the reading means a negative rotation or twist. Twists and rotations are throughout expressed in degrees. Degrees are given to the nearest whole number. The accuracy does not warrant stating fractions, even in averages.

Double Refraction.—A double refracting body may rotate the plane of polarization of linear polarized light. Double

* Maxwell, Elec. and Mag., 3d ed., i, p. 25.

refraction and rotatory polarization may, however, be distinguished if the incident light is polarized in a number of azimuths, for simple double refraction will rotate the plane of polarization in one direction in some azimuths and in the other direction in other azimuths, for it has nothing in its nature to distinguish the two directions of rotation. In these experiments the jelly was always under some strain and, therefore, showed some double refraction. To eliminate the effect of the double refraction, which increased the proper rotation in some azimuths and decreased it in others, and also to obtain greater accuracy, readings were always made, by means of the above mentioned gearing, in eight symmetrically distributed azimuths, and *every position of the analyzer or rotation of the plane of polarization, given below, is the mean of eight such readings.*

Natural Rotation of the Jelly.—The natural rotation of the jelly (usually about $2^\circ{\cdot}7$ per cm.) has been subtracted from the observed rotation in every case and the rotation stated is the difference due to the mechanical strain.

To obtain constant definite results it was necessary to determine what other conditions besides the twist influence the amount of the rotation. These conditions will now be considered in their approximate order of importance.

Conditions Influencing Amount of Rotation.

Lateral Envelope.—Aside from qualitative experiments with glass, the only successful experiments described in previous papers were with jelly in rubber tubes. It was very important to determine whether independent cylinders gave this rotation when twisted. I will give in full the last set of readings with independent jelly cylinders which were made under what previous experience had shown to be the most suitable conditions. The lower clamp was fixed by the clips, *g*, after the twist was applied. As is shown later, it would have been better to have had it hanging free, but these independent cylinders could not support this weight under twist sufficient time for reading the rotation.

Independent jelly cylinders.

July 12, '02. Initial position of the analyzer for uniform color of the two halves of the biquartz = 94.

Length (between rubber clamps) = $5{\cdot}1^{\mathrm{cm}}$. Diam. = $2{\cdot}1$.

1′ delay after applying twist before making readings to avoid relaxation disturbances (see below).

Twist	0	120	−120	120	−120	120	−150	150
	78	88	91	92	83	74	78	85
	79	86	69	91	63	89	69	86
Readings in	82	97	79	97	83	95	76	90
the 8 azimuths	83	89	76	86	75	98	79	92
	86	89	81	88	90	89	81	87
	82	90	70	94	70	89	79	85
	79	98	71	95	82	91	73	86
	78	91	78	92	72	96	73	83
Mean position of analyzer	81	91	76	92	78	91	76	87
Rotation due to twist		−10	5	−11	3	−10	5	−6

Twist	−150	150	−120	120	−150	150
	82	87	94	86	77	85
	79	91	70	89	75	87
	77	91	77	93	79	90
	82	83	79	93	79	86
	83	84	95	85	77	85
	75	88	69	89	83	90
	75	86	87	85	76	87
	74	89	76	94	74	85
Mean position of analyzer	78	87	81	89	78	87
Rotation	3	−6	0	−8	3	−6

The irregularity is not surprising when one considers the strains which are unavoidable in these independent cylinders and the dependence of the rotation upon certain of these strains, as shown later. These and similar observations, some of which are cited below, show qualitatively, that *simple jelly cylinders, without any envelope, acquire when twisted rotatory polarization in the opposite direction to the twist.* It might be suggested that possibly the rotation is due to a twist of the jelly within the rubber tubing. This is scarcely possible, for the rubber is so much more rigid than the jelly that the tubing which tightly grasps the jelly hardly twists at all.

A lateral envelope greatly increases the rotation for a given twist.

Dec. 9, '01. Independent jelly cylinder, length = 8·0, diam. = 2·0.

Twist	−170	190
Rotation	1	−1

Soft rubber tube slipped over jelly (internal diam. = 1·76).

Twist	90	−90
Rotation	−6	9

Dec. 28. Independent jelly cylinder. Length = 7·0 diam. = 1·8.

Twist	210	−220
Rotation	−10	11

Rubber tube slipped over:

Twist	−240	130
Rotation	30	−13

The rotation for a given twist is increased by increasing the envelope.

July 21, '02. Jelly tube. Length (of jelly in tube) = 3·0. Lower clamp free (i. e., suspended from jelly tube and not resting on the platform *e*).

Twist	−120	120
Rotation	8	−4

Wrapped tightly with thin rubber:

Twist	−120	120
Rotation	21	−30

Thin rubber wrapping replaced by a second rubber tube slipped over first rubber tube:

Twist	120	−120
Rotation	−26	11

Longitudinal Compression and Elongation.—It was early noticed that longitudinal compression increased the rotation of the plane of polarization for a given twist, while longitudinal elongation decreased it. Measurements of this effect with the final form of apparatus are given below. The lower clamp was twisted through an angle, read with the graduated circle, *v*, and pointer, *h* (see fig. 1) and clamped to the platform *e* by the clips *g*. The compression or elongation was applied by raising or lowering this platform by the screws *f*. The length of the jelly tube was taken as the distance between two pin points, pricked into the rubber tubing outside the glass disks *l*. Decrease in length we will take as positive and increase as negative.

I. Aug. 2, '02. Jelly tube C 5. Original length = 3·33. Twist of −90.

Change in length (m.m.)	0	·5	1·2	0	−·5	−1·7	−3·9	−4·5	−2·7	0
Rotation	19	26	33	19	16	8	2	1	3	18

II. Aug. 4. Same tube. Twist = 90. (All rotations negative.)

Change in length	0	·9	2	−·8	−1·7	−2	−4·9	−·1
Rotation	18	27	43	16	11	5	4	21

III. Aug. 5. Same tube. Twist = 60. (All rotations negative.)

Change in length	0	2	3·1	·4	—·1	—1	—4	—·3
Rotation	4	9	22	4	2	1	1	2·

I. Aug. 5. Jelly tube D 1. Original length = 3·70. Twist = 120. (All rotations negative.)

Change in length	0	1·6	3	2·4	1·	—·3	—1·2	—2·8	—5	—1
Rotation	9	25	118	75	36	18	10	5	2	9

II. Aug. 6. Same tube. Twist = — 90.

Change in length	0	1·4	2·5	1·2	·5	—1·6	—3·5	—5·4	—2·4
Rotation........	14	35	74	33	14	6	5	1	6

The results for tube C 5 are plotted in fig. 2, and for D 5 in fig. 3, the abscissa being change of length, x, and the ordinate, rotation, y.

Apparently, when $x = \infty$, $y = \infty$; when $x = -\infty$, $y = 0$. This suggests an exponential curve of the general form

$$y = c_1 c_2^x \qquad \text{or}$$
$$\log y = A + Bx$$

where c_1 and c_2 are empirical constants. In fig. 3*a* the ordinates are logarithms of the rotation and the abscissæ are changes of length as before. The closeness of these curves to straight lines indicates that the curves in figs. 2 and 3 are very approximately exponential curves.

If we let x' represent the actual length, i. e., in figs. 2 and 3; x+a constant; when $x' = \infty$ $y = 0$, when $x' = 0$ $y = \infty$, which is satisfied by an equation of the form

$$y = k\frac{1}{x}$$

introducing a few values for x and y from any of the curves shows such an equation to be entirely unsatisfactory.

The above observations demonstrate that *the rotatory polarization of a jelly tube, subjected to a given twist. increases with longitudinal compression and decreases with longitudinal elongation, the change closely following an exponential law.*

Neglect of this condition was the chief cause of the great irregularities in the early work. When the lower clamp rested on the platform, *e*, it made an appreciable difference in the rotation which end of the jelly tube was first clamped, it being clamped in the one case when compressed and in the other when stretched by its own weight. The same tube was quite sure to give different results when taken out and replaced, for it could never be replaced under exactly the same strain. The first attempt to avoid this difficulty was to keep the measured length constant with clamps, but this gave little improvement.

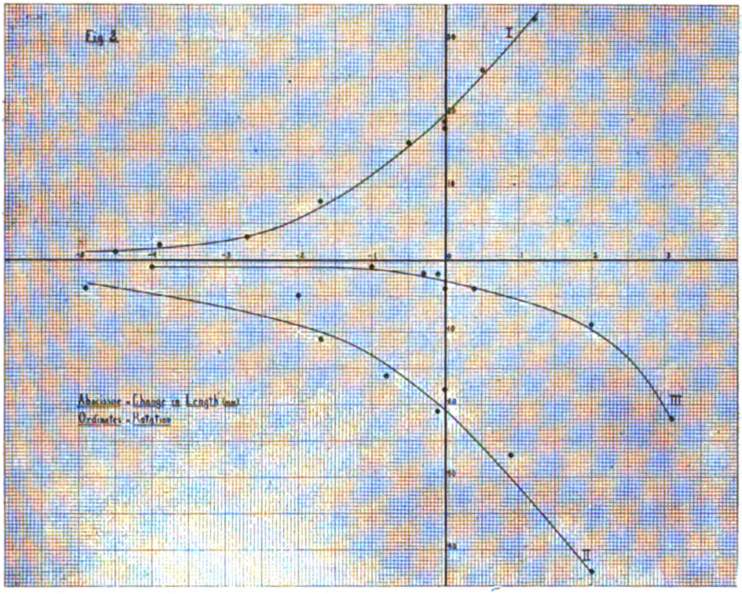


Fig 2.
I
II
III
Abscissae - Change in Length (mm)
Ordinates - Rotation

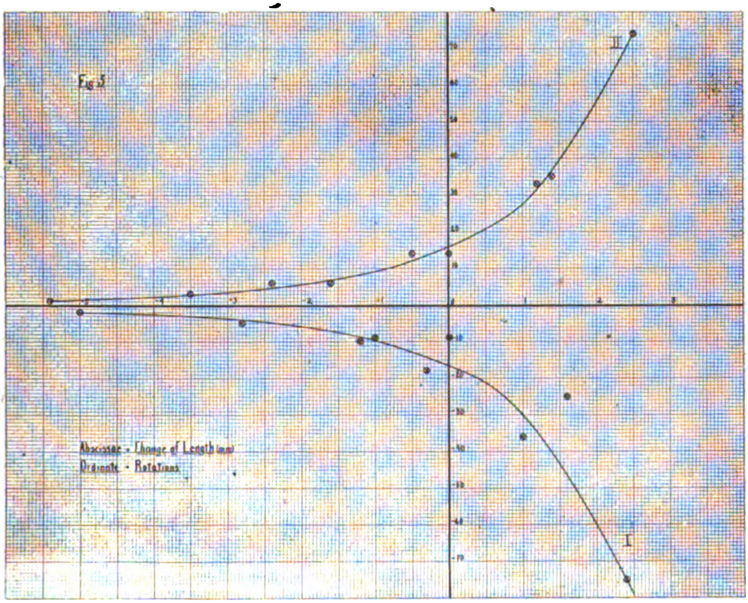
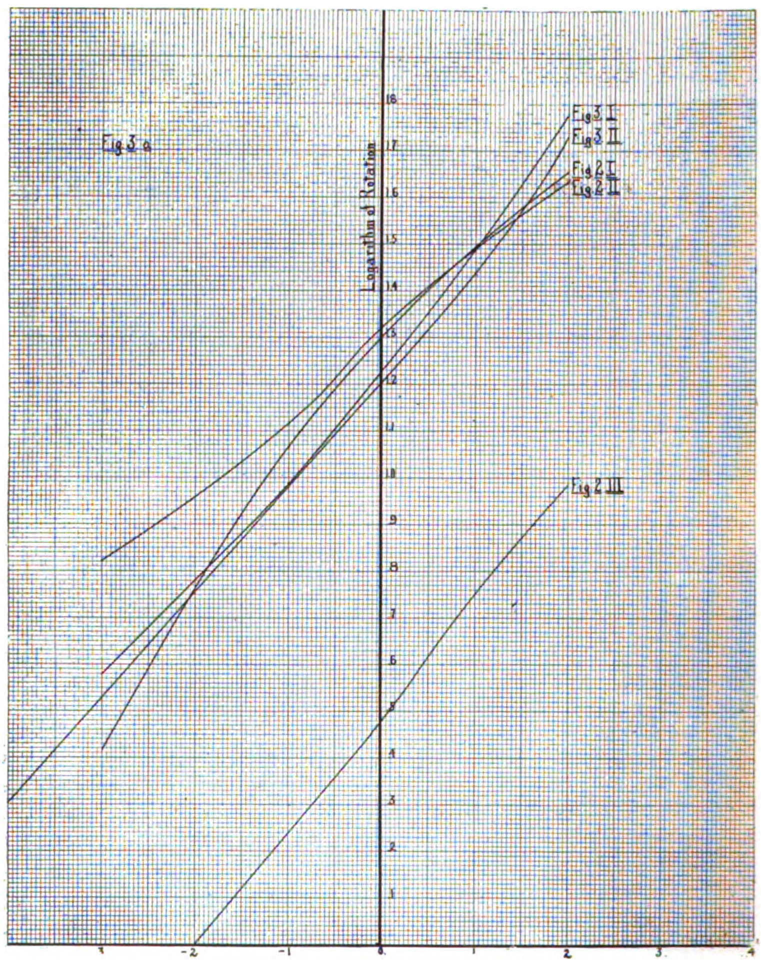


Fig 3
I
II
Abscissae - Change of Length (mm)
Ordinate - Rotations

In the final, vertical form of apparatus the lower clamp could be freely suspended from the jelly tube, simply guided by the ring *i*, and the twist was applied by the cords *x*, great care being taken to have them horizontal.



Change of Length (m.m.).

The following readings show that compression and elongation have no appreciable effect on the natural rotation.

Aug. 5. Tube C 5.

Change of length	0	1·7	3·6	0	—1·1	—3·3
Position of analyzer ..	86	87	87	86	87	86

Tube D 1.

Change in length	0	1·1	2·1	−1·5	−2·9	−5
Position of analyzer ..	35	35	35	36	35	35

Independent cylinders would not endure elongation or compression under large static twist sufficient time to determine the rotation.

Hydrostatic Pressure.—The lateral envelope and longitudinal stress having so great an influence, it was of interest to find the effect of hydrostatic pressure. A jelly tube was clamped under suitable twist by screws passing through an outer, larger, iron tube. This tube with the jelly tube inside was placed inside a still larger iron tube with carefully packed glass windows at the ends. Hydrostatic pressure was applied with an hydraulic pump provided with a pressure gauge.

July 23d. Tube C 3. The pressure is expressed in pounds per square inch.

Pressure	0	80	80
Rotation	32	30	31

July 24th. Tube C 4.

Pressure	0	120	0	160	0
Rotation	50	50	50	51	52

The above are typical examples of a series of observations which demonstrated that up to 160 lbs. per sq. in., *hydrostatic pressure does not affect the rotation.*

*Effect of Previous Strains.**—Relaxation is very conspicuous. If a jelly tube be subjected to prolonged twist the rotation decreases owing to the strain upon the jelly relaxing. For example:

June 25. Tube F 1.

Twist of −100 applied, rotation immediately after = 21
" 2 min. " = 18
" 2 hrs. " = 14

July 5. Tube F 2.

Twist of 120 applied, rotation immediately after = −21
" 3 min. " = −17
" 10 " " = −17

If the rotation is read for a given twist and then a greater twist is applied in the same direction, on returning to the first twist the rotation has decreased owing to the increased relaxa-

* In the four species of relaxation effects the twist is counted from the original reading for zero twist. The variation in the rotation is of course due to change in the zero making the actual twist different from the stated apparent twist.

tion of the strain under the greater twist so that the actual final twist is less than the orginal. Similarly after a prolonged twist in the opposite direction the rotation for a given apparent twist increases, the actual twist being greater than before. Simply one of a great number of examples will be given.

June 24. Tube F 2.

Rotation for twist of 120 after prolonged twist of 0 = — 16
" " " " " 150 = — 14
" " " " " —160 = — 18

If a twist has been maintained for a long time, on returning the tube to its original position for zero twist, an opposite rotation is sometimes observed owing to the jelly having relaxed so much that with the lower clamp in its original position for zero twist, there now is a considerable twist in the opposite direction. For example

June 24. Tube F 2.

Original position of analyzer for no twist = 86. After standing two hours under a twist of —100 which gave a rotation of 13, on apparently removing this twist the position of the analyzer was 87·5, showing a small negative rotation.

To eliminate these relaxation disturbances, (1) a uniform short time (from ½ to 2′ depending upon the tube) should elapse between the application of the twist and the reading of the rotation, that a practically steady state may be reached; (2) the lower clamp should be free, i. e., suspended from the jelly tube as described above, and the twist maintained by the cords, that the position finally taken by the freely hanging lower clamp may be observed before and after each twist is applied.* It is necessary to wait a few minutes in determining the zero, for the approach to a position of equilibrium is asymptotic.

July 11. Tube C 4.

Initial position of lower clamp for no twist = 67.

The first row gives the times after a weight of 180g was applied to each cord, the second row the corresponding position of the lower clamp.

30″	60″	90″	120″
287	285	284	283

Weight removed

30″	60″	90″	120″
61	63	64	64

* This method of determining the true zero, i. e., the position of the lower clamp for no twist, assumes that the rubber tube relaxes the same amount for a given twist as the jelly inside. While making observations described later upon the rigidity of independent cylinders and of rubber tubing, the relaxation of this rubber tubing for a given twist was found to be approximately the same as that of jelly for the same twist.

This asymptotic approach to equilibrium is similar to that observed with metals, only more conspicuous.

Relaxation disturbances can be avoided as described above. There is, however, another effect of the previous history. *A prolonged preceding twist increases the rotation for an immediately following less twist in either direction* but has little influence on a greater twist.

(Relaxation effects eliminated, observations in chronological order.)

July 16. Tube C 3.

Twist	90	120	100	120	90	120
Rotation	−9	−25	for 10′	−29	−12	−27
Twist (cont.)	90	−100	120	90	90	
Rotation "	−11	for 10′	−26	−10	−7	

July 17. Tube C_3.

Twist	90	120	−100	90	120	100	90	120	90
Rotation	−7	−24	for 15′	−11	−22	for 16′	−11	−24	−7
Twist (cont.)	120	100	120	90	−100	120	90	90	120
Rotation "	−24	for 18′	−27	−10	for 21′	−24	−9	−9	−26

This effect is not due to a simple disturbance of the jelly; a prolonged strain is necessary; alternate twists of short duration have little effect.

July 16. Tube C_3.

Twist	90	16 alternate twists	90	90
Rotation	−9	of ± 120 in rapid succession	−9	−9

July 17. Tube C_3.

Twist	90	120	16 alternate twists	120	90
Rotation	−9	−26	of ±100 in rapid succession	−26	−8

As illustrated above, this effect of a previous twist rapidly dies away. Therefore to avoid this disturbance small twists should precede greater and in general some time should elapse between observations.

If we make alternate twists in succession, counting the twist from a constant zero, we notice both effects of previous history. A typical case is the following:

June 26. Tube F 1.

Twist	100	−100	100	−100	100
Rotation	−19	10	−25	11	−28
Twist (cont.)	−100	100	−100	100	−100
Rotation "	12	−28	13	−28	13

Theoretically the relaxation should make the odd rotations, −19, −25, etc., increase, while the even, 10, 11, etc., should slightly decrease. The increase of the latter is due to the other effect of a previous twist, which also causes the odd rotations to increase faster than they would by simple relaxation.

Under *prolonged stress* the rotation increases in contrast to the decrease with prolonged strain.

July 21. Tube C_4. Weight of −180g applied to cords at 10·18.

Time........	10·20	10·30	10·35	10·37	10·45
Rotation....	11	14	+130g applied	−7	−13

July 22. Tube F 1. 180g applied at 11·13.

Time....	11·15	·20	·25	·30	·35	·50	12·08
Rotation	−25	−28	−33	−35	−38	−38	−180g applied

Time (cont.)..	12·08	·11	·21	·37
Rotation " ..	34	39	52	53

The stress being constant, the actual strain is constant but the prolonged state of strain increases the rotation.

Influence of Temperature.—As would naturally be expected, the *rotatory polarization decreases with rise of temperature*, owing to decrease of strain with increased relaxation and a more fluid condition of the jelly. Throughout this work it has been noticed that the softer and more fluid the jelly the less the rotation.

Aug. 6. Tube E 1. Twist of 90.

Temperature	23°	36	37
Rotation.........	−31	−25	−10

Tube E 6. Twist of −90.

Temperature ..	23°	38	38	23	Repeating	23
Rotation	26	15	3	4	Twist	21

The jelly tube was loosely surrounded by an electric heating coil. A thermometer between the jelly tube and the coil gave the temperature.

From the above we should expect that with a given jelly tube, the lower clamp being freely suspended from it and the cords which apply the twist being horizontal, the position of the lower clamp for zero twist being read before and after each twist, sufficient time being allowed for the jelly tube to approximately reach zero twist, a uniform, short time being allowed after the twist is applied before the rotation is read, and a considerable time intervening between a large twist and a succeeding small twist, the temperature being approximately

constant—under these conditions we should expect the rotation for a given twist to be constant and definite. Such is approximately the case, as is illustrated by the following observations, where these precautions have been carefully observed:

Relation between Twist and Rotation.

July 21, A. M. Tube D 3. Length of jelly = $3{\cdot}0^{cm}$. 1′ delay after twist was applied and commencement of readings of rotation.

Twist	−90	90	−110	110	−120	120	−130	130
Rotation..	1	−4	2	−13	2	−18	2	−26
Sum	5		15		20		28	

July 21, P. M. After tube has been removed from the instrument, turned end for end and replaced.

Twist ..	−60	60	90	−90	110	−110	120	−120	130	−130
Rotation	−1	1	−6	0	−13	0	−21	1	−26	1
Sum ...	2		6		13		22		27	

July 22, A. M. After tube has been taken out, turned end for end, and replaced.

Twist ..	−60	60	−90	90	−110	110	−120	120	−130	130
Rotation	0	0	2	−4	2	−11	3	−17	4	−22
Sum....	0		6		13		20		26	

On account of change of zero due to relaxation the actual twists of the jelly, when the rotation was read, were 56, 83, 101, 109, and 118 respectively.

July 22. Tube D 4. Length of jelly = 3^{cm}. 2′ delay between twist and reading of rotation.

Twist	60	−60	90	−90
Rotation....	−8	2	−39	9
Sum........	10		48	

The actual twists were 56 and 83.

July 22. Tube F 1.* Length of jelly = 4^{cm}. 1′ delay between twist and reading.

Twist	−60	60	−90	90	−110	110
Rotation..	1	−1	3	−1	6	−3
Sum......	2		4		9	
Twist (cont.)	−120	120	−135	135	−150	150
Rotation "	8	−4	11	−6	19	−15
Sum "	12		17		34	

* These readings differ widely from those given for this tube on previous pages. The explanation is that in the earlier observations the lower clamp rested on the platform *e* and the jelly tube was longitudinally compressed relatively to what it was here when stretched by the freely hanging lower clamp.

The actual twists were 57, 85, 104, 112, 125, 139 respectively.

Aug. 9. Tube 11. Length of jelly = 3^{cm}. $\frac{1}{2}'$ delay between twist and reading.

Twist	−60	60	−90	90	−110	110	−130	130
Rotation .	0	0	1	−1	1	−2	4	−5
Sum	0		2		3		9	

Twist (cont.)	−150	150	−170	170	−190	190
Rotation "	4	−13	6	−29	16	−57
Sum " ...	17		35		73	

The actual twists were 57, 86, 104, 123, 142, 160, 178.

To illustrate the accuracy of the work, the observations upon tube (43) will be given in full.

Aug. 11. Tube 43. Length of jelly = 3^{cm}. $\frac{1}{2}'$ delay between twist and reading.

Apparent twist	0	90	−90	120	−120	150	−150	170	−170
Corrected twist	0	84	−84	112	−112	140	−140	158	−158
	79	83	73	85	68	90	58	100	50
	81	81	77	86	71	97	61	101	50
	82	85	79	87	74	89	63	94	53
	83	84	81	83	75	90	65	98	56
	82	82	77	84	69	92	63	95	53
	81	83	79	87	73	94	60	100	54
	80	81	73	85	68	93	61	100	54
	80	81	74	81	69	92	60	103	50
Means	81	83	77	85	71	92	61	100	52
Rotation		−2	4	−4	10	−11	20	−19	29
Sum			6		14		31		48

The natural rotation of all the above tubes was about 2·7 per cm.

Dissymmetry in Rotations.—The dissymmetry in the two directions of rotation for apparently the same numerical twist has been very conspicuous. This is partly due to uncertainty of the true position of the lower clamp for zero twist. A slight error will make the actual twist applied in one direction differ from that applied in the other direction by twice this error, and the difference in the rotations will be still greater. The principal cause is probably dissymmetry in the rubber tube. In most of the cases where the dissymmetry was marked the moment was measured which was required to produce a given twist, and in every case it was found that a greater moment was required for a twist in the direction which gave the greater rotation, i. e., for a given twist more force was

applied to the jelly tube, probably in the form of greater constraint upon the jelly by the rubber tube. From the previous results upon the effect of an envelope, the greater rotation would be expected.

For example :

July 21. Tube D 3.

Negative rotations greater.

80g	pull on cords	gave a	twist of	64
−80g	"	"	"	−65
200g	"	"	"	178
−200g	"	"	"	−183

Here we see greater rigidity for positive twists, which produce negative rotations.

Tube D 4.

80g	gave	47	
−80g	"	−49	giving a similar result.
150g	"	91	
−150g	"	−96	

The dissymmetry is not due to the natural rotation, as the excess is as likely to be for one direction as for the other.

As neither rotation is more important, we will study the average, or sum of the two rotations. The observations with tube D 3 are plotted in fig. 4. The observations upon tubes D 4 and F 1 are given in fig. 5 and for tubes 11 and 43 in fig. 6. The abscissæ are twists and the ordinates rotations (sums).

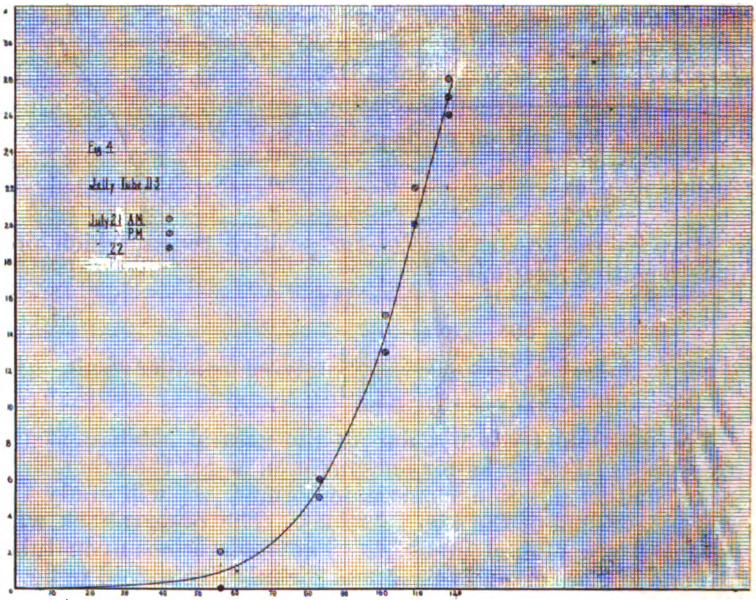
The curves resemble exponential curves of the general form $y=cx^n$ or $\log y=\log c+n \log x$. To determine whether they are such, and if so, of what power, I have plotted in fig. 6*a* the logarithms of the twists and rotations. All of these curves approximate to straight lines, at least for the greater twists, and the inclination of these straight lines is very close to four, giving the very interesting result that, when other conditions are kept constant, *the rotation is closely proportional to the fourth power of twist.*

The curves of the sums of two rotations will have the nature of each one separately, for if the law of one be $y_1=k_1x^n$ and of the other $y_2=k_2x^n$, the equation of the sum will be the same power of the twist, or, $y_1+y_2=(k_1+k_2)x^n$.

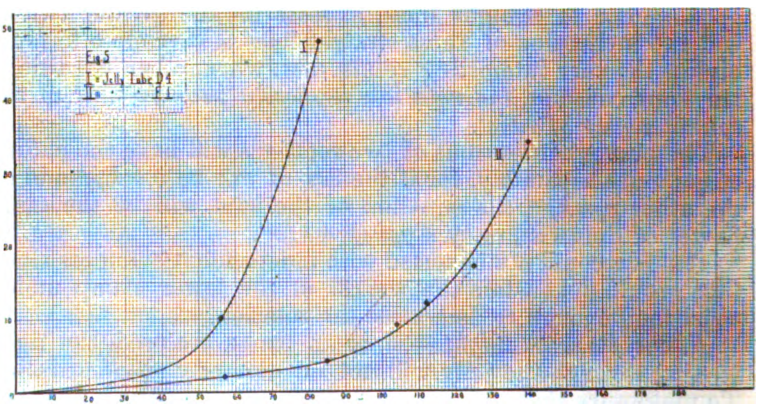
The law could not be tested with independent cylinders since they would not sustain the weight of the lower clamp under twist long enough to determine the rotation.

Plane Parallel Light.—Since no lenses are used, the light passing through the jelly will not be perfectly plane parallel. To make sure that the phenomena are not caused or influenced by this fact (for instance, through reflections from the interior of the rubber tubing, which however is quite dark), a jelly tube was clamped under twist and examined with strictly plane

parallel light from an arc light lantern, which passed in succession through polarizer, biquartz, jelly tube and analyzer.



The position of the analyzer for the untwisted jelly was 35. When the jelly was given a certain unmeasured positive twist

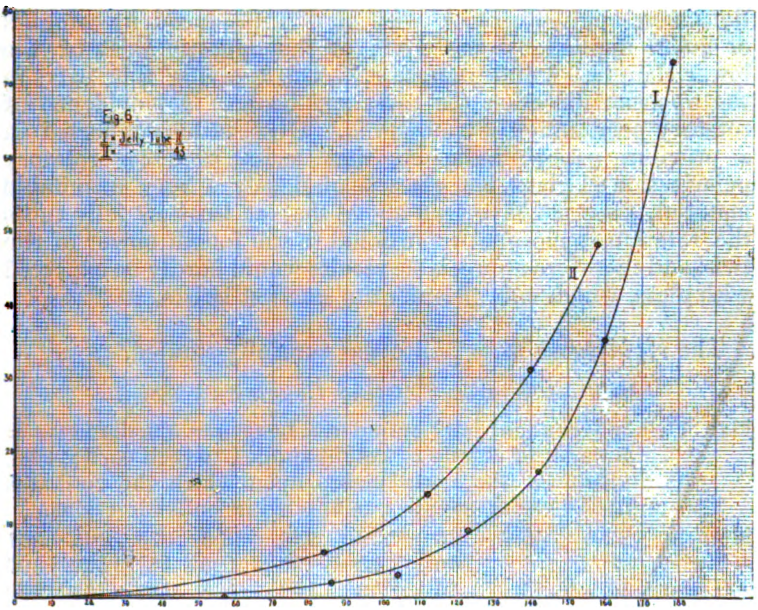


the position of the analyzer was 59 showing a rotation of −24. When the jelly had a certain negative twist the analyzer read 10 showing a rotation of 24.

Glass.—A glass rod was secured from the John A. Brashear

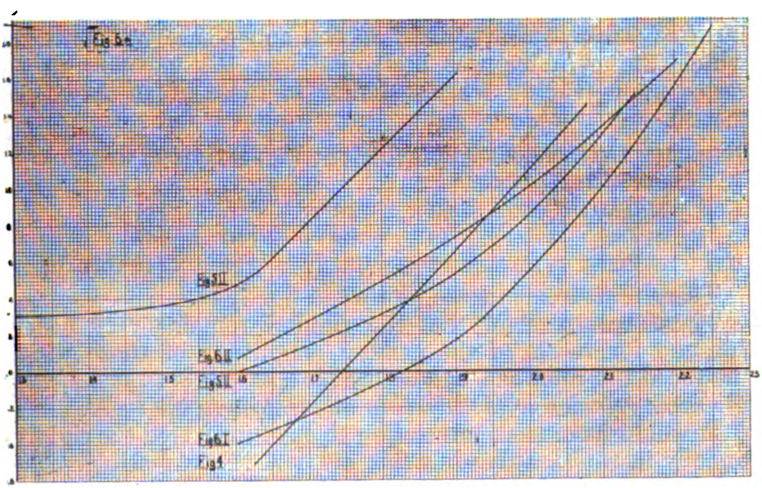
Co., Ltd. of Allegheny, Pa., 11·9^{cm} long, 0·506^{cm} in diameter, with carefully polished ends, perfectly transparent and show-

Rotation.



Twist.

Logarithm of Rotation.



Logarithm of Twist.

ing no trace of strain when examined between crossed Nicols. Circular wood blocks were carefully fitted and glued around the ends. These were fixed in the clamps of the apparatus

described above. The amount of twist was measured by means of a mirror attached to the lower wood block and a distant telescope and horizontal scale. Successive twists in both directions were applied up to a twist of 3°·1 produced by weights of 2030^g applied by the cords to the opposite sides of the lower clamp of 4·58^{cm} diameter.* On applying this twist in the opposite direction the glass rod broke. No evidence of rotatory polarization was observed. Observations reported in a previous paper† indicated that twist produces rotatory polarization in glass, but glass is obviously a very unsuitable material, since we have seen above that at least in jelly tubes the rotation is closely proportional to the fourth power of the twist and therefore appreciable results would hardly be expected with glass, which only permits the smallest twists.

The *rigidity* of these jellies was carefully studied.

Relation between Twisting Couple and Twist.

Mar. 11. Independent jelly cylinder. Length = 5·6, diameter = 2·0. Moment of couple = weight applied to each cord × 4·58, the diameter of the lower clamp upon which the cord was wound. The same couple was applied in both directions.

Moment	22·8	45·8	96	169	238	306	376	466	561
−Twist	9		40	73	102	129	147*	179	207
+Twist	11	21	44	73	102	128	152	186	209

These measurements are plotted in fig. 7, I.

Independent cylinders could not endure such twists if the cylinders were vertical supporting the lower clamp; a modified form of apparatus was used in the above measurements, in which the cylinder was horizontal and the movable clamp rested upon friction wheels similar to those of an Atwood's machine.

July 21. Independent jelly cylinder; (approximate) length = 8, diam. = 2·0.

Moment	22·6	48·7	75	101
+Twist	33	69	110	145
−Twist	32	71	111	148 (broke)

These measurements are plotted in fig. 7, II.

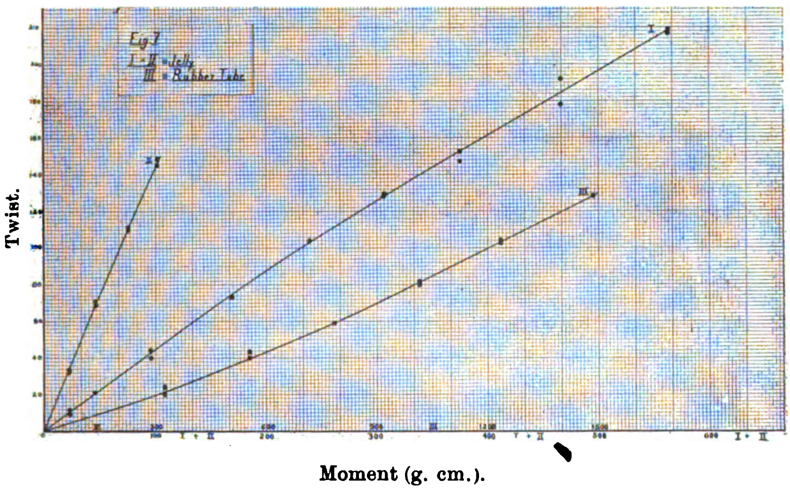
These results show that the rigidity remains very nearly constant for twists of the general magnitude of those which produced the rotations, and before *the rotation is in practically the same relation to the twisting moment as to the twist.*

It would have been interesting to have measured the rigidity of jelly in rubber tubes but this did not prove feasible. The soft rubber tube is so much more rigid than even the stiffest

* These figures give as the rigidity of this glass 2·97 × 10^{11}.
† This Journal (3), viii, 89, 1899.

transparent jelly that practically all the moment applied was applied to the former.

July 22.	Jelly tube 44.		
	Moment applied	366	—366
	Twist	47	—49
Identically same tube empty.			
	Moment	366	—366
	Twist	59	—55
Same tube filled with water.			
	Moment	366	—366
	Twist	59	—57



The unavoidable uncertainty in such measurements is so large a fraction of the difference that no extended observations were made.

Rigidity of Rubber Tubing.—Since the rubber envelope plays so important a part, the relation between couple and twist was investigated for a rubber tube similar to those filled with jelly, but filled with water that the interior might exert a similar resistance to compression as jelly without offering any rigidity.

April 9, '01.			4^{cm} of water.			
Moment	325	555	784	1015	1245	1488
+Twist	20	40	59	80	104	
—Twist	24	43	59	81	103	128

These readings are plotted in fig. 7, III. *The rubber tube closely follows Hook's law within this wide range.*

Does the rigidity have any of the peculiarities of the rotatory polarization?

Rigidity and Previous History.—The rigidity of the jelly does not seem to be influenced by a previous prolonged twist. Aug. 4. Independent jelly cylinder. Length $=7\cdot8$. Cross section $=3\cdot60^{cm^2}$.

Moment of couple......	31·3	−31·3	−31·3	31·3	31·3
Twist..................	48·5	−44	−45	47·5	48

Twist of 80 applied for 25′. Immediately after—

Moment	31·3	31·3	−31·3	−31·3
Twist	48	47	−45	−45

Twist of −80 applied for 50′. Immediately after—

Moment	−31·3	31·3	31·3	−31·3	31·3
Twist	−45	46	48	−45	46

Other series of observations gave the same result.

Rigidity and Longitudinal Extension.—Independent jelly cylinders would endure a prolonged twist if stretched simply by the weight of a light lower clamp, but would not hold any additional weight for stretching the jelly. Therefore the vibration method of determining the rigidity was adopted, and after some failures, considerable success was obtained. The apparatus used was very similar to the mechanical part of the apparatus described above except that the lower clamp, which was freely suspended from the bottom of the jelly cylinder, was as light as possible and had a steel wire projecting below to which could be clamped at right angles either a wood bar or a brass bar. Brass bobs could be attached to the ends of the latter.

The length of the independent jelly cylinder was measured between the relatively inflexible rubber clamps at the ends. The cross section was obtained as follows: Two points were marked on the jelly with aniline ink. The distance between these marks was measured when, first, the jelly was free from any attachments; second, when stretched by the lower clamp; third, with the wood bar additional; fourth, with the brass bar in place of the wood bar, and fifth with the brass bar and bobs. The jelly cylinder, free from any attachments and with carefully cut ends, was placed in a graduated glass sufficiently filled with benzine (which is inert towards the jelly) to cover the jelly. From the change in level of the benzine the volume of the jelly was determined, which with the measured length gave the cross section. The proportional change of length for each weight added being known, the cross section for each weight was determined.

$$n=\frac{8\pi Il}{r^4T^2}$$

I=moment of inertia of mass, attached to lower end of cylinder; T=complete period of vibration, which was measured

with a stop-watch reading to fifths of seconds; l and R are the length and radius respectively of the jelly cylinder.

Data.

Lower clamp; weight 41^{g}. moment of inertia$=50^{g\ cm^2}$.

Brass bar;	weight$=87$,	length $=20·1$,	radius$=0·375$,	mom. of inertia$=2940$
Wood bar;	" $=11$,	" $=17·7$,	" $=0·25$,	" " $=287$
Bobs;	" $=42$,	" mean distance from axis	$=9·05$,	" " $=3450$

Aug. 5. Independent jelly cylinder.

Total length of jelly immersed in benzine						13·95
Volume						51·90
Cross section						3·72
Distance between rubber clamps, no attachments						15·00
"	"	aniline marks	"			10·50
"	"	"	clamp + wood bar attached			10·98
"	"	"	"	brass	"	11·37
"	"	"	"	"	+ bobs "	11·83

Wood bar attached.

$$I=337 \quad l=\frac{10·98}{10·50}\,15·00=15·7 \quad \pi r^2=\frac{10·50}{10·98}\,3·72=3·55$$

Times of 10 vibrations: 7·2, 7·4, 7·4, 7·6, 7·4. Mean $T=0·75$
$n=1·8\times10^5$.

Brass bar attached.

$$I=2990 \quad l=16·2 \quad \pi r^2=3·44.$$

Times of 20 vibrations: 40·6, 40·6, 40·4, 40·4, 40·6. Mean $T=2·03$
$n=2·5\times10^5$.

Brass bar + bobs attached.

$$I=6440, \quad l=16^{g}, \quad \pi r^2=3·30.$$

Times of 10 vibrations: 37·6, 37·6, 37·6 (broke)
$n=7·6\times10^5$.

The rigidity was also successfully measured statically for a shorter length of this same cylinder when stretched by clamp + wood bar.

$$n=\frac{2Ml}{\pi r^4\theta}$$

where M=moment of couple required for the twist θ.

$l=10·8 \quad \pi r^2=3·55 \quad M=13·980\cdot1·74$ (1·74=diameter of part of lower clamp upon which the cord supporting the weight of 13^{g} was wound). Mean value of $\theta=\frac{44}{57·3}$.

$$n=1·8\times10^5 \quad \text{(exact agreement).}$$

Aug. 8. Independent jelly cylinder, (made with a different gelatine from the cylinder of Aug. 5). Omitting details, when the length was 10·40 the rigidity was $1·06\times10^5$ and when the length was 10·83 the rigidity was $1·06\times10^5$.

These results indicate that *the rigidity of jelly increases with longitudinal extension.*

Dispersion.—No success was attained in measuring the dispersion, i. e., the variation in rotatory polarization for light of different wave lengths.

The biquartz could not be used since this is cut for some particular color, in this case to rotate the mean yellow through 90°, giving rise to the "sensitive tint" when placed between parallel Nicols. With simply two Nicols the dispersion was evident. If the analyzer and polarizer were crossed and the jelly introduced, on slightly turning the analyzer the field became green, showing the extinction of the longer waves, and on turning farther in became red, showing the extinction of the shorter waves. When a twist was applied this dispersion was still evident and the positions for the extinction of the different colors seemed farther apart, but no quantitative measurements could be made. When the jelly was twisted the coloration of the fields was irregular. Attempts were made to test the light emerging from the analyzer in both a direct vision spectroscope and an ordinary spectroscope. As the analyzer was rotated, successive parts of the spectrum did not perceptibly fade out, but near certain positions the whole spectrum gradually diminished in brightness until a mininum was reached, and then increased in brilliancy. The position for this minimum could only be determined roughly, but it essentially agreed with the portion of the plane of polarization of yellow light as determined with the biquartz.

Aug. 6. Tube 31. 3^{cm} of jelly.

Position of analyzer; with biquartz = 225, without biquartz for greatest darkness = 226, with the addition of a direct vision spectroscope, for greater general darkness of spectrum = 225.

Twist of 100.

Position of analyzer; with biquartz = 243, without biquartz = 242, with *d.v.s.* = 241.

Twist of —140.

Position of analyzer; with biquartz = 207, without biquartz = 207, with *d.v.s.* = 205.

Quartz plates introduced produced a dark band in the appropriate part of the spectrum, showing that the apparatus was properly adjusted.

Probably dispersion is present and very likely it follows the law of inverse squares of the wave length. The biquartz locates with great sensitiveness the mean position of the plane of polarization of yellow light. Owing to the complicated strains introduced with the twist, there is probably always yellow light polarized in all neighboring azimuths, of only little less intensity and similarly for other colors. Moreover, the jelly appears much more transparent for yellow light than

for other colors. These facts, coupled with the irregularities in location of the plane of polarization of yellow light in different azimuths, as illustrated above where full sets of readings are given, make it natural that the dispersion should not be very clear.

Theory.

With hesitation I suggest the following imperfect theory. In a section of a twisted cylinder, perpendicular to the axis, along any line, whether straight or curved, there is nothing to distinguish one direction of motion from the opposite direction of motion. Therefore for two rays circularly polarized in opposite directions, traversing a twisted cylinder parallel to the axis, the conditions are identically the same in the wave front. Therefore the only difference can be in the lines along which the two opposite disturbances are propagated. The successive points disturbed by a positive circularly polarized ray lie at any instant on a negative spiral and vice versa. Is there anything to distinguish two opposite spirals parallel to the axis of a twisted cylinder? If the side of a spiral farthest from the axis of the cylinder has the same direction of twist as the adjacent part of the cylinder, the side of the spiral nearest the axis must have the opposite direction, and so there would be no distinction between the spirals were it not for the important fact that in a twisted cylinder the stresses and strains increase as we leave the axis radially, and therefore the outside of a spiral has a predominating influence.

Suppose the twist of a cylinder is positive, counting direction the same as for the rays. Any tangential (perpendicular to a radius) square in the cylinder with two of the edges perpendicular to the axis, will be distorted into a rhombus, the axes of strain being the diagonals. Therefore there will be stretching along the outside of the positive spiral and compression along the outside of the negative spiral. We may expect compression to decrease the velocity, for, in general, the denser a body, the slower light is transmitted through it. If this be so, we should expect to see the ray corresponding to the positive spiral to be transmitted faster than the ray corresponding to the negative spiral, or the cylinder having a positive twist and the positive spiral, corresponding to a negative circularly polarized ray, a negative circularly polarized ray will have the greater velocity and the plane of polarization will be rotated in a negative direction. Or, torsion should produce rotatory polarization in the opposite direction to the twist, which agrees with the experimental facts.

The effect of pressure upon the refractive index of jelly was investigated. Pressure was applied to jelly between two glass plates, forming a prism, by varying the angle of the plates. No

conclusive results were obtained owing to the great double refraction, introduced by the compression. Jelly is very incompressible.*

I do not see how in the above theory to account for the effect of the envelope unless the envelope affords a constraint preventing the jelly from yielding under the strains produced by the twist, the more perfectly these strains are maintained the greater being the rotatory polarization.

Consider the above mentioned rhombus into which the square has been distorted. The distortion will bring the diagonal along which there is compression nearer the axis than the other diagonal. Therefore longitudinal compression will increase the compression along this diagonal more than it will decrease the elongation along the other diagonal, and therefore we should expect the rotatory polarization to be increased, which agrees with the experimental facts. Similarly we should expect elongation to decrease the rotatory polarization, which it does. On this theory we are not surprised that hydrostatic pressure produces no effect, since it is perfectly symmetrical and homogeneous.

This rotatory polarization might be expected in a general way according to many theories of rotatory polarization which require rotatory polarization where there is such dissymmetry present as in a twisted body.

Conclusions.

The following are the most important facts added to those established in previous papers.

1. For a given twist, the rotatory polarization is very much increased by an envelope about the jelly.

2. The rotatory polarization of jelly twisted in a rubber tube is very much increased by longitudinal compression, and decreased by longitudinal elongation, closely following an exponential law.

3. It is not affected by hydrostatic pressure.

4. It is, to some extent, dependent upon the previous history of the jelly.

5. When these disturbing influences are kept constant the rotatory polarization is quite definite for a given twist and,

6. The rotation is closely proportional to the fourth power of the twist.

7. The rigidity of the jelly increases with longitudinal elongation.

Finally, a theory has been suggested for explaining some of the above facts.

I wish to acknowledge my indebtedness to Prof. A. Wilmer Duff for many valuable suggestions and criticisms.

Worcester Polytechnic Institute, Worcester, Mass.

* P. von Bjerkén, Wied. Ann., 1891, p. 817.

ART. XXXVII.—*The Use of the Zinc Reductor in the Estimation of Vanadic Acid;* by F. A. GOOCH and R. D. GILBERT.

[Contributions from the Kent Chemical Laboratory of Yale University—CXVI.]

THE reduction of vanadic acid to the condition of vanadium tetroxide preparatory to estimating it by titration with potassium permanganate is generally accomplished by the use of sulphurous acid or hydrogen sulphide. The more convenient method of treatment by zinc and free acid is not directly applicable on account of the irregular reduction of vanadic acid under the conditions to a stage approximating that of the dioxide, as was first shown by Czudnowicz.* The work herein described is the result of an attempt to find a reliable method for bringing the product of reduction of vanadic acid by zinc and acid definitely to the condition of the tetroxide, in order that the reductor so useful in the preparation of salts of iron for titration by potassium permanganate may be made similarly applicable in the estimation of vanadic acid and its salts.

A very convenient form of reductor† was made as follows: The contracted end of a piece of glass tubing, 2^{cm} in inside diameter and 50^{cm} long, was sealed to a stop-cock prolonged in a smaller tube, $0{\cdot}5^{cm}$ in inside diameter, to a length of 24^{cm}. At the point of contraction in the larger tube was placed a piece of platinum gauze, next to this a mat of fine glass wool 2^{cm} in thickness, and upon the last a column 40^{cm} long of amalgamated zinc of a size to pass a sieve of eight meshes to the centimeter. The smaller tube passed through a rubber stopper fitted to a vacuum flask and the last was connected through a pressure regulator with the vacuum pump. In using this apparatus the pump was started, the regulator set to give a pressure in the flask less than the outside pressure by an amount equal to 20^{cm} of water, the reducing column of zinc was warmed by passing through it hot distilled water followed by 100^{cm^3} of hot 1 per cent sulphuric acid, and then the solution of the salt of vanadic acid to be reduced was gradually drawn through the zinc in small portions, alternating with portions of the 1 per cent sulphuric acid amounting to 100^{cm^3}. Finally, the column was washed down with 100^{cm^3} more of the dilute sulphuric acid and about 250^{cm^3} of hot distilled water. Throughout the entire series of operations care was taken to keep the zinc covered with liquid and so out of contact with the air.

The lavendar solution collected in the flask contains vanadium dioxide, which when exposed to the action of a current of air takes, as Roscoe has shown,‡ the blue color of the

* Ann. Phys., cxx, 39 (1863).
† Described in Blair's Chemical Analysis of Iron, p. 93 (edition of 1902).
‡ Ann. Pharm. Suppl., vi, 98 (1868).

tetroxide. The first attempts, therefore, to bring about definiteness of condition were made along the lines of Roscoe's observation. The solutions obtained in the receiving flask were treated by air at various temperatures and for various lengths of time, and then, after heating to 80°, were titrated with nearly $\frac{N}{20}$ potassium permanganate standardized by reference to $\frac{N}{20}$ arsenious oxide.

This most exact method of standardizing the permanganate was carried out by adding a convenient volume (43^{cm^3}) of the permanganate to a solution of potassium iodide (3 grm.) acidulated with sulphuric acid (3^{cm^3} of the 1 : 1 acid) contained in a glass-stoppered flask fitted with a funnel tube and trapped, introducing through the funnel tube an excess of a standard solution of $\frac{N}{20}$ arsenious oxide, neutralizing with acid potassium carbonate, and titrating in presence of starch with iodine also standardized against the arsenious oxide.

In blank experiments made from time to time with the reductor it was found that the reading color developed in the acid solution only after the addition of $0{\cdot}2^{cm^3}$ of the standard permanganate, and this correction, due to traces of iron in the zinc and the considerable volume of the solution, was applied in the experiments in which the vanadium salt was treated. In our experiments ammonium vanadate was the salt of vanadic acid employed and the sample with which we worked contained 76·66 per cent of V_2O_5, as determined according to the iodometric method of Holverscheit.*

The results of some attempts under most favorable conditions to effect the oxidation of the reduced trioxide to the condition of the tetroxide by the action on air are given in Table I. These show plainly that, although the oxidation by air appears to proceed rapidly at the outset, the complete conversion of the lower oxides to the tetroxide by such action takes place with too great slowness and uncertainty to form the basis of a reliable and rapid quantitative method.

TABLE I.

Time of treatment by air. min.	Temperature.	V_2O_5 taken. grm.	V_2O_5 found by titration with $KMnO_4$. grm.	Error. grm.
75	56°—28°	0·0767	0·0778	+0·0011
75	60°—29°	0·0767	0·0805	+0·0038
75	48°—29°	0·0767	0·0829	+0·0062
75	†100°—	0·0767	0·0772	+0·0005
75	†100°—	0·0767	0·0769	+0·0002

* Inaug. Diss. Berlin, 1890, p. 49.
† Brought twice to the boiling point during this interval.

The action of the molecular oxygen of the air is obviously insufficient to bring about the complete oxidation of the lower vanadium oxides in acid solution to the condition of the tetroxide within a reasonable time, and ordinary oxidizers carry the action too far, oxidizing the tetroxide as well as the lower oxides. We have found, however, that silver oxide and silver salts will supply oxygen in a condition of activity sufficient to affect the lower oxides easily while leaving the tetroxide intact. Silver sulphate appears to be the most convenient form in which to use the silver compound.

In making our experiments with silver sulphate the solution of the vanadic acid was treated in the reductor in the manner described except that the receiving flask was charged at the outset with a saturated solution of silver sulphate —100^{cm^3} in each of the first six experiments; 300^{cm^3} in the last two. The contents of the flask were boiled and then filtered upon asbestos in a perforated crucible. The solution, now about 700^{cm^3} in volume, was heated again to the boiling point and titrated with $\frac{N}{20}$ potassium permanganate. When the reduced solution issuing from the reductor meets the silver sulphate a muddy deposition of finely divided silver begins; but upon boiling the mixture the metallic silver gathers into a single spongy mass and leaves the solution so clear that were it not that spongy silver is easily acted upon by the permanganate* the titration might be made without previous filtration.

TABLE II.

V_2O_5 taken.	$KMnO_4$ required, nearly $\frac{N}{20}$.	V_2O_5 found.	Error.
grms.	cm^3.	grms.	grms.
0·0767	17·	0·0770	+0·0003
0·0767	17·04	0·0771	+0·0004
0·0767	17·05	0·0772	+0·0005
0·0767	16·96	0·0768	+0·0001
0·0767	16·98	0·0769	+0·0002
0·0767	17·	0·0770	+0·0003
0·1918	42·9	0·1942	+0·0024
0·1918	42·7	0·1933	+0·0015

The results of these experiments are given in the accompanying table. For the smaller amounts of vanadium the determinations are accordant and exact. The wider variations in the last two experiments are probably due to the difficulty of catching the pink end reaction in presence of the reddish yellow color which appears as the vanadic acid is formed in considerable amount. This is a difficulty inherent in the permanganate process of titration when large amounts of vanadic acid are involved.

* Giles: Chem. News, xv, 204 (1867). Otto van der Pfordten: Ber. d. d. Chem. Ges., xx, 3375. Friedheim: Ber. d. d. Chem. Ges., xx, 2554.

ART. XXXVIII.—*On the Composition of some Canadian Amphiboles;* by B. J. HARRINGTON.

THE writer is indebted to the Rev. W. P. Borhart, B.A., for specimens of a beautiful variety of amphiboles from the township of Grenville in the Province of Quebec. It had been mistaken for garnet notwithstanding its characteristic amphibole cleavage and optical characters. The specimens received are all massive and most of them show, in addition to eminent prismatic cleavage, a jointed structure, the jointage planes making various angles with the cleavage planes. The color is reddish-brown and the mineral shows a degree of transparency not commonly found in the species. Flakes obtained by cleavage exhibit an extinction angle of 16°. The specific gravity was found to be 3·110 at 15° C. and the hardness 6 or a little over. In composition the mineral is interesting on account of the large proportion of fluorine which it contains. The presence of this element has been observed in many amphiboles but as a rule in much smaller quantity. The quantitative analysis of a specimen of the mineral gave the following results:—

Silica	45·50
Titanium dioxide	0·68
Alumina	12·25
Ferric oxide	0·28
Ferrous oxide	0·75
Manganous oxide	0·11
Lime	13·31
Magnesia	20·63
Soda	2·76
Potash	1·76
Water	0·40
Fluorine	2·80
	101·23
Oxygen equivalent to fluorine	1·17
	100·06

Another specimen gave 2·93 per cent of fluorine, a larger proportion of this element than has been observed in any other amphibole, so far as the writer is aware. It was estimated by Rose's method, and on converting the calcium fluoride into sulphate the amount obtained in each case agreed almost exactly with the theoretical. The water was estimated directly by fusing in a platinum boat with the mixed carbonates of sodium and potassium in a current of dry air and collecting in a chloride of calcium tube. In the dry atmosphere

of a Canadian winter, potassium carbonate can be used with perfect safety. The combustion tube was protected by platinum foil, as recommended by Penfield, and heated by means of a blast-lamp. The titanium was estimated colorometrically.

In a general way the composition of the Grenville amphibole resembles that of a bright green variety from Pongas in Finland analyzed by Rammelsberg (I) and also one from the same place analyzed by Bonsdorff (II). Their results were as follows :*

	I	II
Silica	46·12	46.26
Alumina	7·56	11·48
Ferrous oxide	2·27	3·48
Manganous oxide	....	0·36
Lime	13·70	13·96
Magnesia	21·22	19·03
Soda	2·48	....
Potash	1·29	....
Water	1·10	....
Fluorine	2·76	2·86
	98·50	97·43
Sp. gr.	3·104	....

Another Canadian amphibole which has been analyzed is that occurring in the essexite of Montreal, a rock constituting portions of the mountain. The specimen examined was from the coarse-grained rock found in the Protestant cemetery and its separation from the other constituents was effected in part by means of a dense liquid. The mineral is black by reflected, and brown by transmitted, light and shows marked absorption. The hardness is between 5 and 6, the specific gravity, at 17·5° C., 3·159, and there is a well-defined prismatic cleavage. The composition is given under I, while under II is given that of a similar amphibole from the essexite of Mount Johnson, analyzed by Mr. Nevil Norton Evans of this university :—

	I	II
Silica	39·23	38·63
Titanium dioxide	4·53	5·04
Alumina	14·38	11·97
Ferric oxide	2·92	3·90
Ferrous oxide	8·56	11·52
Manganous oxide	0·65	0·73
Lime	11·70	12·81
Magnesia	13·01	10·20
Soda	3·05	3·14
Potash	0·98	1·49
Water	0·36	·33
	99·37	99·76

* Quoted by Hintze in his "Mineralogie," p. 1239.

Neither mineral was examined for fluorine.

The similarity in composition of these minerals from eruptive masses twenty-five miles apart is striking and so is the general resemblance in composition to the "basaltic hornblendes" from a number of European localities as given by Schneider.*

Department of Chemistry and Mineralogy,
McGill University, Montreal.

* Zeit. für Kryst. u. Min., xviii, 579, 1891. See also paper by Dr. F. D. Adams, entitled "The Monteregian Hills, a Canadian Petrographical Province," which is about to appear in the Journal of Geology.

ART. XXXIX. — *The Andover Meteorite;** by HENRY A. WARD.

THE State of Maine has long had three meteorites to its credit: Nobleboro 1823, Castine 1848, Searsmont 1871. All are stones, and all fell in the southern half of the state. We now give first public record to a fourth, also from south of the middle parallel of the state, and also an aerolite. We owe the first knowledge of this to Mr. Henry V. Poor, of Brookline, Mass., the present owner of the mass. This gentleman obtained the specimen from the original owner, on whose farm, adjacent to his summer residence in Andover, Oxford Co., Maine, it fell. Mr. Poor, with great liberality, placed it at my disposition for examination and description. I further received a letter from Mr. Lincoln Dresser, of Andover, who tells the whole story of its fall. Mr. Dresser says, "The meteor that fell near my house on the morning of Aug. 5th, 1898, was witnessed by me, and I was within 25 feet of it when it came down. It came from the northwest at an angle of 75 degrees, and in all probability came from the constellation of Perseus (!). It was accompanied by a loud noise resembling a buzz saw, and had a following of smoke. It was in intense heat when it struck a stone in the wall, grazing the stone. In its fall it passed down through the branches of an elm tree, cutting many of them off as cleanly as if done by a sharp knife. I supposed at the time it was a gaseous ball of fire, and thought it exploded, but after examination I found where it imbedded itself in the earth to the depth of 2½ feet. I secured, by digging, a large piece weighing 7½ lbs., and two or three small ones which were broken by its striking the rock fence. The large piece was irregular in shape and had the appearance of having exploded in the air, as a large piece was lost from one side before it went into the ground. The crust of this one on three sides had a blackened surface with shallow dents, like finger points. The broken part shows a gray rock, looking like silver. The break was fresh, and on exposure to the air you could observe the iron coloring in it. It was of the finest of granite. People in the adjoining towns heard the peculiar buzzing noise, and heard a loud report, probably when it burst."

In June, of the present year, I had the privilege of visiting the spot in Andover where the stone fell. A sharp dent in the granite wall still shows freshly where the stone struck at its first impact. In falling it had passed through thickly set, small branches of an elm tree directly above. Mr. Dresser

* Read before the Rochester Academy of Science, November 10, 1902.

tells me that it was seeing these branches fall, cut off by the stone, which had changed his first instant's impression that the latter was of a gaseous character. By the aid of a ladder and a saw I obtained the portion of a branch two inches in diameter, half cut through by the meteorite. I also obtained two small pieces of the stone itself, one from Mr. Dresser, and another from Mr. E. M. Bailey, also a resident of Andover. Through the kind favor of Mr. Poor I am able to here present a cut of the large mass, which weighs about 6½ lbs.

Andover Aerolite; about three-fifths actual size.

In general shape it is an irregular lengthened polygon like a flattened triangle, with the three points largely truncated. The cut presents one side whose largest dimensions are 7¾ inches in length by 4 inches in greatest breadth. The opposite side, which was broken off in the fall, is of the same length, but 5½ inches in the measure at right angles. All other sides are well coated with a brownish black crust, relieved by occasional patches of lighter brown. The crust is roughened by little, slightly raised pimples, often connected with very short ridges, of the molten matter. On several sides are shallow pittings as large as the impressions of finger-ends. Some of these are separated, others confluent, the latter, as is to be expected, all on the same side of the mass, having their depressed rim in the same direction or aspect. The broken side of the mass shows an interior of a light gray color, and is granular, with a few chondri of much darker color. The whole mass is, in a fresh fracture, brilliant with points of nickeliferous iron sparsely interspersed with bronze-colored troilite. I have given the name of Andover to this meteorite from the proximity of its fall to the town of Andover, Oxford Co., Maine.

620 Division St.,
Chicago, Ill.

ART. XL. — *A Pseudo-Serpentine from Stevens County, Washington;* by F. W. CLARKE.

IN the course of an investigation upon the ornamental stones of Stevens County, Washington, Mr. R. W. Thatcher and Professor Elton Fulmer, of the State Agricultural Experiment Station, examined a supposed serpentine which proved to have quite anomalous composition. To the unaided eye the rock was ordinary serpentine of a typical yellowish green color; it was fairly homogeneous, and capable of receiving a fine polish. Incomplete analyses, however, by both of the above named chemists showed that it was not serpentine, and as I had been consulted with regard to the interpretation of the data, a sample was sent to me for more exhaustive study.

According to Professor S. Shedd of the Washington Agricultural College, who is conducting the investigation, the rock is from the quarry of the United States Marble Company, 12 miles north and west from Valley, a station on the Spokane Falls and Northern Railroad. It outcrops on the face of a high bluff at an elevation of about 4,070 feet above sea level, and forms a wedge-shaped mass cutting across the mountains in a direction 5° west of north. The adjacent rocks are slates, which lie conformably upon a very coarsely crystalline, dark, almost black, magnesian carbonate. The "serpentine" itself varies a good deal in color, and a series of samples in the U. S. National Museum show that the output of the locality is far from uniform. They range from a white carbonate, through various intermediate mixtures of the verde antique type, to material which appears to be ordinary serpentine. The latter, however, as shown by the serpentine under consideration, is distinctly laminated in structure, and exhibits a splintery fracture. An analysis by Mr. George Steiger gave the following results:

SiO_2	13·08	H_2O at 100°	·85
Al_2O_3	1·63	H_2O at above 100°	23·94
Fe_2O_3	1·25	CO_2	2·03
FeO	·19		
MgO	56·44		99·74
CaO	·33		

These figures at once suggest a probable admixture of brucite with the serpentinous material, and a microscopic examination by Mr. J. S. Diller tends to confirm this supposition.

According to Mr. Diller the specimen is mainly composed of three minerals, *a*, *b*, and *c*. The first two have nearly equal indices of refraction, but differ widely in birefringence. The mineral *a* is the most abundant. In transmitted light it is

colorless, but between crossed nicols it exhibits brilliant colors. The mineral *b* is pale green, and intermingled with *a*. Its birefringence yields weak colors, quite characteristic of chlorite. In quantity it is less than one-fourth of *a*.

Mineral *c* is granular, in scattered grains and irregular groups with a high index of refraction and a birefringence which suggests a carbonate, but it does not effervesce with a dilute acid. It amounts to not more than 5 per cent of the whole. Mineral *b* is certainly chlorite, and *a* may be brucite or possibly serpentine.

By applying Mr. Diller's observations to the analysis of the rock, the proximate composition of the latter may be deduced; although certain assumptions must be made. The carbonate present is probably hydromagnesite, for that species is a frequent associate of brucite. The composition of the chlorite is unknown, but it may be interpreted as essentially clinochlore, and proportional to the ferric oxide and alumina. So much assumed, the analysis gives the following approximate results expressing the composition of the specimen:

Hydromagnesite	5·0	Extraneous water	1·0
Chlorite	14·0		
Serpentine	20·0		100·0
Brucite	60·0		

In this, four minerals appear instead of three, but the microscopic examination did not attempt to discriminate between the brucite and the serpentine.

In order to obtain evidence confirmatory of the foregoing conclusions, a few experiments were made, tending towards fractional determinations. Upon digesting the powdered rock for two hours with cold, dilute nitric acid (10 per cent by volume), 1·32 per cent of $Fe_2O_3 + Al_2O_3$ and 47·29 per cent MgO went into solution. In a similar experiment with cold, 20 per cent acetic acid, 0·69 $Fe_2O_3 + Al_2O_3$ and 45·64 MgO were extracted. Brucite dissolves readily in acids of the indicated strength, but some chlorite was evidently attacked as well. I also found that ordinary serpentine was quite appreciably acted upon by weak acetic acid. These experiments then merely show that the rock contains a large amount of magnesium in a very easily soluble condition, the quantity equivalent to 60 per cent of brucite being 41·4. The results are in harmony with the conclusions already reached, and help to support them, although accurate fractional determinations can not be made. The rock is unusual in character, and if the sample examined is fairly characteristic of the entire deposit, the latter should be carefully studied in reference to its origin and its geological relations.

U. S. Geological Survey, Washington, D. C.

ART. XLI.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from p. 176.]

CLASSIFICATION OF THE PRIMATES.

IN dividing this order into its primary branches, the first and most necessary step is to obtain, if possible, a clear and comprehensive understanding of the essential or fundamental features which characterize the several lines upon the basis of their evolution. It is naturally to be expected, that, as we approach the point of common origin, these features will become less and less accentuated, and those characters which in the final development have become most pronounced, will be found to be inconspicuous and apparently of little significance in the beginning.

It should be also remembered, that, while some of the phyla have progressed along the lines of their final development with comparative rapidity, and have modified many of the characters which were more or less common to all Primates in the earlier stages of their history, others have retained the primitive features to a greater or less extent. Thus, the presence of such characters as an increased number of premolars, the tritubercular condition of the molars, the small size of the cerebral lobes, with the greater or less development of their several parts, the presence of a floccular fossa of the skull, a third trochanter of the femur, or an entepicondylar foramen of the humerus, the possession of claws instead of nails on the terminal phalanges, as well as many other similar characters, are to be looked upon as common primitive features which characterize all early Primates. Any one of the phyla may have separately and independently modified these features according to the requirements of a new environment.

As an example in illustration of this statement, one might meet with a Primate in which the premolars were much reduced in number, in which the molars were fully quadritubercular, the face much shortened, the brain highly developed, the temporal and orbital fossæ separated by a bony plate; in short, in which might be found many of the characters of the most highly developed Primates; but if, at the same time, the specimen exhibited the peculiarities of the incisors, canines, and the caniniform lower premolar, as well as the cerebral circulation characteristic of the lemurs, one could be perfectly certain that the species was genetically related to and belonged in the Lemuroidea and was not a

member of the Anthropoidea.* We therefore finally come to learn what the essential or fundamental characters really are, and in proportion as our knowledge increases in this direction, in just that proportion shall we be able not only to arrange the species, genera, families, etc., in their true and proper relations to each other, but at the same time may feel assured that such an arrangement represents something more than a mere convenience.

As long as we hold fast to the old horizontal system, our classification will be artificial and unsatisfactory. This is nevertheless ofttimes necessitated by our lack of knowledge, but whenever evidence from the extinct forms is to be had, sufficient to furnish even an incomplete glimpse at the phyletic history, we shall always obtain much more satisfactory results by arranging our classification accordingly. It is by reason of this increase in our knowledge of extinct forms that frequent innovations are necessary, in order to give some expression to the general affiliations which the new discoveries reveal. Our knowledge of the more exact relationships of the various representatives of the Primates is still far from complete, yet I am persuaded that a considerable advance over the older conceptions is now not only possible but urgently demanded. The classification herein proposed introduces some novel features, which may or may not stand the test and be justified by future discovery, but it none the less denotes an effort to give expression to some of the genetic affinities of the several known types of the order, which a study of the extinct forms reveals.

It has been customary to include among the Primates the North American Hyopsodidæ, a small family containing two genera and some four or five species, which are limited in their vertical distribution to the Middle and Upper Eocene strata. Hitherto, nothing has been known of the skeleton, and consequently they have been placed in various positions within the order. In the skull, of which a fairly complete specimen was found by me in the Washakie Basin, Wyoming, in 1895, and is now preserved in the collections of the American Museum, there is no ossified tympanic bulla, and the carotid canal enters the cranium as in the Insectivora. The *foramen ovale* is placed well within the alisphenoid, and is not a notch

* Such an example was, in fact, an actual occurrence. Dr. Forsyth Major discovered an extinct Primate in Madagascar, which he named *Nesopithecus*. From the unusually high development of the skull, and its many resemblances to the higher apes, he concluded that it was an Anthropoid. Lydekker, however, justly criticised this view, and pointed out that, owing to the distinctly lemurine character of the incisors and the caniniform enlargement of the first lower premolar, it should be classed as a highly developed Lemuroid.

in its posterior border completed by the periotic, as is so frequently, if not universally, the case in the lemurs. The incisors are three above and below, and the lachrymal canal is located within the orbit. Although not positively known, it is probable that the lachrymal did not have an extraorbital extension. The pattern of the molars is unlike that of any known Primate, but in many respects is like that of certain primitive Ungulates. From several fragmentary skeletons in the Marsh collection, I am now fortunately able to state that the limbs were totally unlike those of the Primates. In the presence of a supertrochlear foramen, the humerus differs from that of any known Primate. The metapodials do not display the typical globular heads of those of the Primates, but are depressed and strongly keeled at their distal ends. The phalanges are short and stout, and give to the foot a distinctly terrestrial rather than an arboreal character; and, lastly, may be noted the very important character of a completely nonopposable hallux. The North American Hyopsodidæ do not, in fact, possess a single Primate feature, as far as can be discovered, but on the contrary are much more like the Insectivora, to which order I refer them. A summary of the foregoing characters, in which they differ from typical Primates, may be given as follows:

(1) There are three incisors above and below; (2) there is no ossified tympanic bulla; (3) the structure of the molars is not like that of the Primates; (4) the entocarotid circulation is like that of the Insectivora; (5) the limb bones differ from those of any known Primate; (6) the metapodials are not Primate; (7) the phalanges are short; and (8) the hallux is not opposable.

It would appear from the evidence obtained that there are no less than three distinct primary divisions of the order now known, and as these represent as many subordinal groups, the Primates have accordingly been divided into three sections.

The first group which is deserving of a subordinal rank among the Primates, although not commonly admitted, is that represented by the living Aye Aye of Madagascar. Along with this go the American Eocene genera *Mixodectes*, *Cynodontomys*, *Microsyops*, *Smilodectes*, and *Metacheiromys*. The most distinctive and important features of this group consist in the enlargement of the central pair of incisors, the limitation of the enamel to their anterior faces in the later forms, in consequence of which they wear into chisel-shaped points, and, finally, their growth from persistent pulps. Concomitantly, the outer incisors and canines disappear, and the mandibular condyles as well as the glenoid fossæ become modified and adapted to a longitudinal, instead of a vertical

movement of the lower jaw, as in the Rodentia. The entocarotid circulation in *Cheiromys* is like that of the lemurs; the lachrymals are large, with extraorbital extension, and the external opening of the lachrymal canal is outside of the orbit. As in the lemurs, the lachrymal and malar are in contact. *Cheiromys* also agrees with the lemurs in having the fourth digit of the manus the longest of the series, and, except for the hallux, the terminal phalanges are clawlike. In all, there is a well-ossified tympanic bulla, and the limbs and feet are elongate and fully adapted to arboreal life.

Owing to the wide separation both in time and space, it has been doubted whether there is any genetic connection between the aberrant Madagascar species and the extinct North American forms. Indeed, Osborn has recently placed the American series in a primitive suborder of the Rodentia, which he calls the Proglires. After a careful investigation of the evidence, I do not hesitate to state it as my belief that the Madagascar and American forms are intimately related. There can be no two opinions respecting the Primate affinities of *Cheiromys*. This has long since been settled beyond all dispute, and although but comparatively little of the skeleton of the American species is known, what is known betrays the same Primate stamp with equal distinctness. In the New World forms, we have the following conditions presented: Ancient primitive Primates undergoing a rodent-like modification of the central pair of incisors, together with the disappearance of the outer pair and the canines. In American genera, the process is progressive but incomplete, while in the living Madagascar species the modification is complete. No stronger general argument, it seems to me, could be put forth in favor of their relationship, especially when it is remembered that these are the only representatives of the Primates in which the slightest tendency toward such modification is shown. That so distinctive and profound a change could have originated twice independently, in the same order, is so highly improbable as to be unworthy of serious consideration. That the group is of pre-Tertiary origin is shown by the fact that *Mixodectes*, its oldest representative, is already highly modified in the Torrejon or second stage of the Lower Eocene. I propose for the suborder the slightly modified term Cheiromyoidea.

The second suborder of the Primates includes the lemurs, a group which has long been recognized by zoologists as constituting a primary division of the order. Some authorities are inclined to deny the genetic connection of this group, as well as that of the Cheiromyoidea, with the true monkeys, and assign to them a separate and independent ordinal rank. This,

however, is manifestly incorrect, as all the evidence from both living and extinct forms tends to show.

Their chief characters derived from the skeleton are the following: Like the preceding group, the main entocarotid does not enter the tympanic chamber; the lower incisors and canines, when present, are much compressed laterally, elongate, and procumbent in position; the first lower premolar is commonly enlarged, and functions as a canine; there is a well-ossified tympanic bulla; the fourth digit of the manus is the longest of the series; the lachrymal is very generally enlarged, with extraorbital extension, and the external opening of the lachrymal canal is always upon the outside of the orbit;* the lachrymal and malar are nearly always in contact.

Just what value is to be attached to the placentation, in estimating affinities, is a question difficult to decide, but it is believed, and strongly argued by some, that the lowly organized structures and generalized condition by means of which the fœtal envelopes develop a connection with the lining membrane of the uterine walls during gestation furnish a sufficient reason for removing the lemurs widely from the monkeys. In like manner, the rudimentary condition of the posterior cornu and hippocampus minor of the cerebrum, as well as the convolution of the transverse colon, have been looked upon as characters of great significance in classification. While it is probably true that these characters derived from the soft anatomy indicate a wide distinction between existing monkeys and lemurs, yet it is much to be doubted whether these distinctions would not assume very small proportions, or completely disappear, did we have an Eocene monkey with which to make the comparison.

Touching the question of the value of the manner of placentation as applied to the classification of the Mammalia, it is well to recall the words of Flower and Lydekker on this topic. In speaking of the "deciduate" and "non-deciduate" varieties of placenta, they say:† "It was once thought that the distinction between those two forms of placentation is so important as to constitute a sufficiently valid basis for a primary division of the placental mammals into two groups. It has, however, been shown that the distinction is one rather of degree than of kind, as intermediate conditions may exist, and it is probable that in different primary groups the simpler, non-deciduate form may have become developed independently into one or other of the more complex kinds. * * * * * We may conclude

* An exception to this last statement is found in the extinct Malagassy lemur *Nesopithecus* of Forsyth Major. In this species, according to its describer, both the lachrymal and the lachrymal opening are within the orbit.

† Mammals, Living and Extinct, 1891, p. 80.

that, although the characters and arrangement of the fœtal structures may not have that extreme importance which has been attributed to them by some zoologists, they will form, especially when more completely understood, valuable aids in the study of the natural affinities and evolution of the Mammalia."

In view of the important fact that the soft anatomy of extinct forms is wholly inaccessible and will remain forever hidden from us, and furthermore, not knowing exactly what value to attach to characters derived from this source among living forms, it seems by far the safest plan to rely largely, if not solely, upon osteological evidence for our conclusions respecting the affinities and evolution of the various groups of the Mammalia. The facts afforded by the skeleton are the only ones whereby we are permitted to make a direct comparison between the structure of living and extinct forms, and should, therefore, always be ranked as of the first importance.

The following are the chief primitive characters of the lemuroid skeleton: The cranial cavity is proportionately small; the face is generally large and elongate in comparison with the size of the brain case; the temporal and orbital fossæ are not separated by a bony plate (except in *Nesopithecus*); the zygomata are usually broad and heavy, and the malar frequently extends beneath the zygomatic process of the squamosal to near the glenoid fossa, as in the Marsupials; the malar articulates with the lachrymal in front in many species, thereby shutting out the maxillary from a share in the anterior or lower rim of the orbit; there is usually a considerable interorbital breadth; the squamosal has little vertical expansion on the side wall of the skull; there are nearly always large postglenoid foramina; the posterior free edge of the hard palate is thickened; the molars are for the most part tritubercular; the atlas has separate openings for the two divisions of the suboccipital nerve; the ilium is generally little expanded; the head of the femur is more or less sessile upon the shaft; the digital fossa has a slitlike form; the second trochanter is large and internal in position, and there is always a third trochanter; the proximal plantar extremity of the metatarsal of the hallux, for the attachment of the long peroneal tendon, is enlarged and prolonged; the second digit of the pes bears a terminal claw, and the humerus has an entepicondylar foramen.

It is at present difficult to decide just how many families should be recognized in this suborder. A conservative estimate would not place them above two or perhaps three. Of these, the living species would constitute one, the Lemuridæ; the extinct Malagassy *Nesopithecus* a second, the Nesopithecidæ, and very doubtfully the extinct *Megaladapis* a third, the

Megaladapidæ. It should be remembered, however, that the Lemuridæ, as thus constituted, include forms of very diverse structure and probably not very closely related. Thus the Indrisinæ, usually considered as one of the best-marked and most distinct subfamilies, in the absence of one pair of incisors or canines in the lower jaw, together with the strongly developed mesostyle of the superior molars, appear to be sufficiently differentiated from the central forms of the typical lemurs to be entitled to a distinct family rank.

The third and last primary division of the order is the Anthropoidea, and in the present state of our knowledge it seems quite impossible to obtain any very clear insight into the phyletic history of the various groups composing it. Until much additional information is secured concerning many of the fossil types already known, as well as of the large number of undiscovered connecting forms which must have certainly existed, any attempts at a classification that may be regarded as final can not at present be made. Still, certain advance steps may, I think, now be taken, which will help considerably toward a final solution of some of the many difficult problems involved in unraveling the tangled web of simian evolution.

The characters by means of which the members of the group are distinguished from the two foregoing suborders are as follows: Incisors reduced to two pairs above and below (in *Tarsius*, one below); they have a normal form and position; there is no caniniform enlargement of the first lower premolar; the entocarotids traverse the petro-tympanic; the lachrymal canal (except in one group) is more or less confined within the orbit, and the facial part of the bone is quite generally reduced; the lachrymal and malar are not in contact, leaving the maxillary a share in forming the anterior rim of the orbit; the fourth digit of the manus is never the longest of the series.

It would appear from present evidence that the Anthropoidea early divided into at least three main branches, but the exact lines of descent from these starting points can not now be traced with any degree of certainty, among the majority of the living species. The first of these divisions is represented by the living marmosets, a group which Huxley classified under the name of the Arctopithecini.* Their chief claim to distinction consists in the lack of opposability of the hallux and pollex; the clawed condition of all the terminal phalanges of both manus and pes, except a slight flattening of that of the hallux; the loss of the third molar above and below, and the tritubercular condition of the superior molars. These characters, except the last, are unique among the Primates, and may or may not indicate a very ancient branching from the main

* Anatomy of Vertebrated Animals, 1872, p. 392.

axis. Whatever classification is finally adopted, it seems to me that this should be regarded as one of the primary divisions of the suborder, since the characters of the extremities are not found in any other member of the order thus far known.

In the second division of the Anthropoidea, I included *Tarsius* and its allies. It has been customary with nearly all authorities to classify this species in the Lemuroidea, assigning to it the rank of a separate and distinct family. Hubrecht,* however, from a careful study of its placentation has shown that in this respect it is widely different from the lemurs and decidedly like the monkeys. Hence, he has proposed its removal to the Anthropoidea. In confirmation of this view, it may be added that the entocarotid circulation, which I am inclined to regard as of fundamental importance, is analogous to that of the primitive monkeys and not like that of any of the lemurs. Similarly, the lack of union between the malar and lachrymal is found in all the monkeys, and the reverse condition in the lemurs. The teeth do not exhibit that peculiar modification seen in all lemurs, but again are like those of the monkeys; and, lastly, the fourth digit of the manus is not the longest of the series as in all the lemurs, but is shorter than the third as in the monkeys. Thus, it will be seen that the evidence derived from five independent sets of organs, the placentation, lachrymo-malar union, entocarotid circulation, dentition, and digital lengths of the manus, all concur in assigning to *Tarsius* a position with the monkeys and not with the lemurs. On the other hand, it may be stated that in the extraorbital extension of the lachrymal and the location of the external openings of the lachrymal canal outside the rim of the orbit, it agrees with the lemurs.

This question of the lachrymal region in the skull of the Primates has recently formed the subject of extensive and painstaking research by Forsyth Major.† From his investigations, we learn that, with the single exception of *Nesopithecus*, a highly developed extinct type from Madagascar, all the lemurs possess an enlarged lachrymal which reaches beyond the orbit, while the external opening of the lachrymal canal is situated upon the side of the face. In some species, notably *Loris*, no lachrymal was found, but there can be little doubt that its absence is due to early fusion with the maxillary and complete obliteration of the sutures, as in the sea-lions and seals. Another interesting observation recorded by Dr. Major relates to the lachrymal enlargement seen in certain South

* Die Keimblase von Tarsius. Festschrift für Carl Gegenbaur, Leipzig, 1896. The Descent of the Primates, Princeton Lecture, 1897.

† On Some Characters of the Skull in Lemurs and Monkeys, Proc. Zool. Soc. London, February, 1901.

American apes, as the howlers and woolly spiders, wherein it is impossible to decide whether the lachrymal canal can be said to be within or without the orbit. In view of these transitional conditions, the great taxonomic significance of the position of the lachrymal canal, which it was formerly thought to possess, is materially weakened. The large lachrymal with the opening of the canal extraorbital in position is undoubtedly the primitive condition. This is demonstrated by reference to the Marsupials, in some of which, notably *Myrmecobius*, it is unusually large and sends a considerable spur outward upon the zygoma to join the malar. In all Insectivora, Rodentia, and primitive Carnivora, the enlarged lachrymal as well as the extraorbital position of the canal, is, as far as I am aware, universal.

For views in favor of retaining *Tarsius* in the Lemuroidea, as well as for a general discussion of the genetic relationship of the latter to the Anthropoidea, I refer the reader to the excellent papers by Mr. Charles Earle.*

If *Tarsius* is a member of the suborder Anthropoidea, of which in my judgment there can be little question, then it appears equally certain that, with its allies, it represents an independent branch from the main axis, and one, moreover, of equal rank with the Arctopithecini, or marmosets, since its primitive lachrymal arrangement associated with precocious tooth reduction, as well as with some peculiarities of the pterygoid region, mark it off distinctly as a side branch. I suggest for this group, therefore, the name Paleopithecini.

Of the extinct American types, *Euryacodon* and *Anaptomorphus* are names which probably refer to one and the same genus. The skull structure of the best-known species, *Anaptomorphus* or *Euryacodon homunculus*, was described by Cope from an exceptionally fine specimen found by me in the Wasatch bed of the Big Horn Valley, Wyoming, in 1881. This specimen has recently been refigured by Osborn.† Its resemblance to *Tarsius* is so striking that there can be apparently no question whatever of the near relationship of the two. This is seen in the following important characters: The entocarotid canal traverses the tympanic chamber, and its external orifice is situated as in *Tarsius;* the malar does not unite with the lachrymal; the lachrymal is relatively large and extends out upon the face; the external opening of the lachrymal canal is extraorbital in position; the auditory bullæ are much inflated and the external alæ of the pterygoids extend outward and backward in such a manner as more or less to enclose the bullæ; the structure of the teeth

* Science, February 12, 1897; and May, 1897. American Naturalist, July and August, 1897.

† American Eocene Primates, Bull. Amer. Mus. Nat. Hist., June, 1902.

resembles that of *Tarsius* very closely, and the premolars in the Bridger species at least are reduced to two; there is no lemurine modification of the incisors or first lower premolar; the brain is relatively large, and the face is considerably bent down on the basicranial axis, as in *Tarsius;* while, lastly, the species are small and the orbital cavities enlarged.

From this striking array of similarities which Cope was careful to point out, I am fully convinced that the two forms are closely related and should be placed in the same group. In like manner, we may feel reasonably certain in arranging the extinct European *Necrolemur* of Filhol in the same group. Although the skull characters are less perfectly known than in the American species, yet the lachrymal region, the dentition, and the general appearance of the single skull known, all betray the same fundamental resemblances to *Tarsius* noted in *Anaptomorphus* or *Euryacodon.* I do not hesitate, therefore, to classify it with this series. The same may also be true of the imperfectly known *Microchœrus* of the European Eocene, but this is not at all certain. There is some evidence that the latter genus is closely related to and represents *Hyopsodus* in Europe.

The position of the remaining American genera, *Omomys*, *Hemiacodon*, and *Washakius*, is more problematical. No complete skull of any of these forms is known, and it is impossible to say whether they most resemble *Tarsius* or the monkeys. In one species, *Hemiacodon gracilis*, a fragment of the maxillary is sufficiently preserved to show that there was no union between the malar and lachrymal. The incisors do not display any lemurine characteristic and the inference is tolerably clear that they belong either with the Paleopithecini or with the true monkeys. I may add just here that there is such a marked resemblance between the teeth of *Omomys* and those of certain of the living South American Cebidæ, that I am strongly inclined to the belief that these extinct forms are true monkeys.

There yet remains to be discussed another group of extinct Primates whose remains are better preserved, and hence more completely known, than any others yet discovered in the Eocene, the Adapidæ of Europe and the so-called Notharctidæ of America. Cope* arranged them in the group Mesodonta, which he made a suborder of his order Bunotheria. He included in the Bunotheria the suborders Creodonta, Mesodonta, Insectivora, Tillodontia, and Tæniodonta, at the same time holding that the Prosimiæ, or Lemuroidea, should be placed here as well. He seems to have entertained the opinion that all were ordinally distinct from the Quadrumana, or Primates, although

* Tertiary Vertebrata, 1884.

he does not state this directly. He defined the Mesodonta as follows: "Incisors not growing from persistent pulps; molars tubercular, never sectorial; third trochanter elevated; astragalus not grooved above." Under the head of Prosimiæ, he further adds, "The suborder may be differentiated from the Mesodonta by the possession of an opposable hallux of the posterior foot," but qualifies this definition with the statement that the lack of opposability of the hallux is not demonstrated in any of the species except *Pelycodus*.

There seems to be a great deal of confusion in Cope's statements regarding the classification of the genera under the Mesodonta and Prosimiæ. In the Mesodonta, he classified the following genera: *Omomys*, *Microsyops*, *Pantolestes*, *Tomitherium*, *Pelycodus*, *Sarcolemur*, *Hyopsodus*, *Aphelicus*, *Adapis*, and *Opisthotomus*. In the Prosimiæ, on the other hand, he included three families, viz.; Adapidæ (genera not stated), Mixodectidæ comprising the genera *Mixodectes*, *Microsyops*, and *Cynodontomys*, and the Anaptomorphidæ including *Anaptomorphus* and *Necrolemur*. It will be thus seen that several of the genera are referred to both suborders.

The next authority of note to contribute to this subject is Schlosser. He regarded all these early extinct forms as constituting a group equal in rank to that of the Lemuroidea and Anthropoidea, and one from which these two, in all probability, have been derived. This group he named the Pseudolemuroidea. Osborn in his recent paper, "American Eocene Primates,"* inclines apparently to the same view. He says: "Three suppositions are possible: First, that these Primates represent an ancient and generalized group (Mesodonta, Cope) ancestral to both Lemuroidea and Anthropoidea; second, that they include representatives of both Lemuroidea and Anthropoidea, contemporaneous and intermingled; third, that they belong exclusively to one or the other order. There are certain advantages in the revival of the term Mesodonta Cope, a suborder (anticipating the terms Pseudolemuroidea and Tarsii) which would bear somewhat the same relationship to the modern specialized Monkeys and Lemurs that the Condylarthra bear to the Ungulata and the Creodonta to the Carnivora."

As regards the validity of the group Mesodonta of Cope and its suggested revival by Osborn, very little need be said. From the most abundant skeletal materials of both *Adapis* and *Notharctus* we now know that the hallux was almost if not quite as opposable as in any living Primate. Cope's statement, therefore, of its lack of opposability in *Pelycodus*, a genus scarcely distinct from *Notharctus*, must with almost absolute

* Loc. cit.

certainty be erroneous. His technical definition of the group, moreover, as well as its dissociation from the Primates, I regard as utterly unsound, illogical, and in no wise warranted by the facts. I do not believe that any such natural group exists, and a revival of the name Mesodonta can result only in confusion. As we have already seen, there are types of very different affinities among these ancient Primates, and this fact in my judgment effectually precludes the possibility of their association into a single group. What position, then, do *Adapis* and *Notharctus* occupy with reference to these natural groups already outlined? That they can not be consistently placed in the Lemuroidea is evident for the following reasons: The incisors do not exhibit any traces of lemurine modification, but, on the contrary, are like those in typical monkeys; the main entocarotid canal traverses the petro-tympanic chamber as in *Tarsius;* the lachrymal and malar do not unite on the anterior rim of the orbit; the digital lengths of the manus are not known with certainty, but in *Notharctus*, the evidence is reasonably conclusive that the fourth was not longer than the third.

On the other hand, their resemblance to the Paleopithecini is more marked. This is seen in the greatly inflated condition of the tympanic bullæ as well as in the outward and backward extension of the external alæ of the pterygoids. These forms differ from the Paleopithecini, however, in having a more reduced lachrymal, in the position of the external opening of the lachrymal canal on or near the rim of the orbit, in having a greater number of premolars, and in general in being larger and of more robust proportions. Thus, it will be seen that they occupy a position intermediate in many respects between the remaining Anthropoidea and the Paleopithecini. In the latter, there seems to have been a marked tendency toward precocious specialization in both tooth reduction and brain enlargement, which are curiously associated with retention of the primitive condition of the lachrymal. *Adapis* and *Notharctus*, on the other hand, exhibit advance in the reduction of the lachrymals, but retain the more generalized features of the dentition and brain enlargement. These are the essential differences between the two lines and mark out very distinctly the trend as well as the possibilities of their future development. It is in just such a group as that which includes *Adapis*, *Notharctus*, and *Limnotherium*, that we must seek for the beginnings of the higher monkeys and apes which follow; and while these species, at present the only well-known types of the series, may not have been in the direct line of descent, they can not at the same time have been far removed from it. *Omomys* and *Washakius*,

as far at least as we are permitted to judge from their scant remains, are closely related to *Adapis* and *Notharctus*, but had made greater progress in the reduction of the premolars. This gives an especially monkey-like appearance, pointing particularly in the direction of certain living Cebidæ. It is probable, therefore, that all this series should be classified as primitive members of a third section of the Anthropoidea. If this last division represents a homogeneous and natural group, equivalent in rank to that of the Arctopithecini and Paleopithecini, it is deserving of a name, and I suggest for it that of Neopithecini.

A summary of the foregoing discussion of the classification of the Primates, together with the more technical definitions of the several groups, is embodied in the following statement:

Limbs elongate, with prehensile manus, and pes fully adapted to an arboreal life; incisors enlarged and in later forms becoming reduced in number and rodent-like in pattern; canines disappearing in later forms; an ossified tympanic bulla; entocarotid circulation as in the Galaginæ and Lorisinæ; three families, Microsyopsidæ, Metacheiromyidæ, and Cheiromyidæ.
Cheiromyoidea.

Limbs elongate, prehensile, and adapted to an arboreal habit; incisors of lower jaw reduced in size, pectinate, and proclivous in position; anterior lower premolar very generally enlarged and functioning as a canine; entocarotid canal not traversing the petro-tympanic; malar and lachrymal very generally in contact on anterior rim of orbit; fourth digit of the manus the longest of the series; three families, Lemuridæ, Indrisidæ, and Nesopithecidæ. Lemuroidea.

Limbs elongate, extremities prehensile, and fully adapted to an arboreal life; incisors and canines normal in form and position; entocarotid traversing petro-tympanic; malar and lachrymal not in contact on anterior rim of orbit; fourth digit of manus shorter than third; three superfamilies or groups, Arctopithecini, Paleopithecini, and Neopithecini. Anthropoidea.

The definitions and divisions of the superfamilies of the Anthropoidea are as follows:

Hallux and pollex of manus and pes not opposable; true molars reduced to two in each jaw; one family, Hapalidæ.
Arctopithecini.

Hallux and pollex fully opposable; three true molars; lachrymal enlarged, with well-developed *pars facialis;* lachrymal canal opening without orbit; premolars precociously reduced in highest forms; two families, Anaptomorphidæ and Tarsiidæ.
Paleopithecini.

Hallux and pollex fully opposable; three true molars; lachrymal reduced; lachrymal canal opening on or inside orbital rim; premolars progressively reduced to two in advanced forms; brain enlargement progressively increasing in the later types; five families. Neopithecini.

The Neopithecini are divisible into at least five distinct families of which in the living fauna three are confined to the Old World* and one to the New World. One extinct family is common to the two hemispheres, and as far as can be now ascertained from the remains, occupies a position not far removed from the common primitive stem from which the great majority of the living simian population of the Old and New Worlds originated. In the case of the Old World families, the gap is as yet very wide, but in the case of the New World Cebidæ, the interval is much less, and is not greater than one would be reasonably led to anticipate between an ancestor of Upper Eocene time and a living descendant. In fact, the difference is not nearly as great as it is between the modern horse and its Upper Eocene progenitor, *Orohippus*. As this phase of the subject will be more fully discussed in another section of the present paper, it may be here dismissed.

The families of the Neopithecini are distinguished upon osteological considerations, as follows:

Premolars four above and below; orbital and temporal fossæ more or less freely continuous; parietal uniting with alisphenoid on side wall of cranium; molars more or less fully quadritubercular, with ridges of superior trigon distinct; a large petro-tympanic bulla expanded behind; external auditory meatus not prolonged into a tube; carotid canal piercing bulla near postero-external angle; a postglenoid foramen; muzzle elongate; lachrymal slightly extended beyond rim of orbit, with opening of lachrymal canal upon edge of orbit; ilium little expanded; ischium without distal enlargement or everted edges; head of femur more or less sessile upon shaft; digital fossa of femur narrow and slitlike; a third trochanter and an entepicondylar foramen; hallux fully opposable; metatarsal of hallux with elongate proximal plantar extremity; pollex not as fully opposable as in higher species; foramina of atlas complex. Adapidæ.

Premolars three above and below; orbital and temporal fossæ separated by bony plate; parietal uniting with alisphenoid on side wall of cranium; frontal excluded from contact with alisphenoid by malar on side of skull (except in *Mycetes* and some species of *Ateles*); molars fully quadritubercular, with ridges of superior trigon distinct; first lower premolar without elongate

* In this statement, the origin of man is considered to have taken place in the Old World.

anterior border, as in preceding family; petro-tympanic bulla little expanded behind; no vaginal process; auditory meatus not prolonged into a tube; carotid canal piercing bulla near postero-internal angle; a large floccular fossa on internal surface of periotic; postglenoid foramen present or absent; muzzle abbreviated; lachrymal either slightly extended beyond rim of orbit or confined wholly within it; ilium well expanded; ischium without distal enlargement and edges not everted; head of femur with well-defined neck and an open digital fossa; no third trochanter; an entepicondylar foramen of humerus; hallux fully opposable; metatarsal of hallux without elongate proximal plantar extremity; pollex not as fully opposable as in higher species; foramina of atlas complex. Cebidæ.

Premolars two above and below; orbital and temporal fossæ separated by bony plate; no parieto-sphenoid but a temporo-frontal contact in the side wall of the cranium; frontal and alisphenoid not separated by malar on side wall of cranium; molars fully quadritubercular of squarish outline, without traces of superior trigonal ridges, but tending to the formation of cross crests; first (third) inferior premolar with characteristic elongation of anterior border; petro-tympanic bulla little inflated and filled with cancellous tissue; no vaginal process; auditory meatus prolonged into a bony tube; carotid canal piercing bulla near postero-internal angle; a large floccular fossa on inner surface of periotic; presphenoid and basisphenoid remaining long distinct, as in preceding family; no postglenoid foramen; muzzle abbreviated; lachrymal never reaching rim of orbit, and of much greater vertical than transverse extent; ilium well expanded; ischium with distal enlargement and everted edges; head of femur with well-defined neck and an open digital fossa; no third trochanter; no entepicondylar foramen of humerus; hallux fully opposable; metatarsal of hallux without elongate proximal plantar extremity; pollex fully opposable; foramina of atlas complex or simple. Cercopithecidæ.

Premolars two above and below; canines enlarged and of greater vertical extent than premolars and incisors, as in preceding families; orbital and temporal fossæ distinct; a temporo-frontal contact on side wall of skull (except in Orang); frontal and alisphenoid not separated by malar on side wall of cranium; molars fully quadritubercular, with more or less rounded outline, without any tendency to the formation of transverse crests, but with distinct remains of superior trigonal ridges; first (third) inferior premolar with traces of elongate anterior border (least distinct in Chimpanzee); petro-tympanic bulla little inflated, with a moderately well-developed vaginal process (except in *Hylobates*) and no ossified styloid process as in preceding families; auditory meatus elongate; carotid canal as in Cercopithecidæ; floccular fossa on internal surface of periotic vestigial;

no postglenoid foramen; presphenoid and basisphenoid early coössified; lachrymal confined within the orbit, having a quadrate outline without vertical enlargement (except in *Hylobates*); ilium expanded; ischium with only moderate distal enlargement and without strongly everted edges (except in *Hylobates*); head of femur with well-developed neck and open digital fossa; no third trochanter; no entepicondylar foramen; hallux and metacarpal of hallux as in Cercopithecidæ; pollex fully opposable; sesamoids of flexor tendons of four outer digits in manus and pes vestigial or wanting and keels absent (except in *Hylobates*); foramina of atlas simple; as in the preceding families, the mastoid process is rudimental or wanting and the premaxillo-maxillary suture long persists, being obliterated only in aged specimens; there is no foramen spinosum for the passage of the middle meningeal artery, but a notch in the anterior external part of the foramen ovale apparently represents it in the Gorilla and Chimpanzee; the frontals meet in the middle line over the presphenoid and behind the ethmoid (except in Orang). Simiidæ.

Premolars two above and below; canines reduced and of no greater vertical extent than premolars and incisors; orbital and temporal fossæ distinct; a spheno-parietal contact on the side wall of cranium (variable); frontal and sphenoid not separated by malar on side wall of skull; molars fully quadritubercular with superior trigonal ridges distinct; first (third) inferior premolar without any trace of elongate anterior border; no petrotympanic bulla; but a well-defined vaginal process and a well-ossified and coössified stylohyal; external auditory meatus and carotid canal as in Simiidæ; no postglenoid foramen; no floccular fossa on inner surface of periotic; presphenoid and basisphenoid early coössified; lachrymal confined within the orbit, having a much greater vertical than antero-posterior diameter; distal enlargement of ischium reduced and edges not everted; neck of femur and digital fossa as in Simiidæ; hallux enlarged, not opposable and in line with other digits; keels, grooves, and sesamoids of four outer metapodials of manus and pes absent; foramina of the atlas simple; a well-developed mastoid process; the maxillo-premaxillary suture early obliterated; a distinct foramen spinosum for the passage of the middle meningeal artery; no union of frontals over presphenoid and behind ethmoid. Hominidæ.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *The Atomic Weight of Cæsium.*—An elaborate revision of the atomic weight of cæsium has been made by RICHARDS and ARCHIBALD. The material used in this investigation was chiefly a large quantity of cæsium salts from the pollucite of Paris, Maine, which Wells of the Sheffield Scientific School had purified by his method of recrystallizing the salt $CsCl_2I$, and which was so pure that the authors were unable to improve upon its purity. Three methods of atomic weight determination were used; the analysis of the chloride, which consisted in comparing cæsium chloride with silver chloride and with silver; the analysis of cæsium bromide, with analogous comparisons; and the ignition of cæsium nitrate with an excess of pure silica, where cæsium nitrate was compared with N_2O_5. Indirect comparisons with potassium chloride and oxide were also made. The close agreement of the individual results and of the results by the different methods is very remarkable, and there is no doubt that the atomic weight of this rare element is now known with the highest degree of accuracy. As an outcome of forty-two analyses involving seven different ratios and three compounds of cæsium (the chloride, bromide and nitrate), the authors calculate the atomic weight of cæsium to be 132·879, if oxygen is 16. The result shows that the early work done upon this atomic weight in the Sheffield Laboratory by Johnson and Allen, was remarkably exact.—*Proceedings Amer. Acad.*, xxxviii, 443. H. L. W.

2. *Conductivity Produced in Gases by the aid of Ultra-Violet Light.*—In a former paper Professor TOWNSEND confirmed the results previously published by him, on the theory of the genesis of ions by collision. It was shown that the negative ions thus produced in a gas are identical with the negative ions set free from the negative electrode by the action of ultra-violet light. Professor Townsend has now extended his results in experiments with hydrochloric acid gas and water vapor, with the result that the same theory of genesis affords an explanation of the phenomena and we are led to conclude that negative ions are generated in air, carbonic acid gas, hydrogen, water vapor, or hydrochloric acid gas, which are all identical with the negative ions set free from a zinc plate by the action of ultra-violet light. It is shown that a negative ion may pass inside the sphere of action of a molecule without producing new ions.—*Phil. Mag.*, April, 1903, pp. 390–398. J. T.

3. *Absorption of Gravitation Energy by Radio-active Substances.*—H. R. Geigel published in the Ann. der Physik, 10, p. 429, 1903, some results tending to show evidence of this absorption. W. KAUFMANN, of the Physik. Inst. d. Univ. Göttingen,

has repeated Geigel's results and finds that they are explained by thermal disturbances in the process of weighing.—*Ann. der Physik*, No. 4, 1903, pp. 894–896. J. T.

4. *Emanations of Phosphorus.* — G. C. Schmidt shows that the electron theory does not explain these emanations and concludes that there is no evidence of the production of ions or electrons by the slow oxidization of phosphorus. The conductivity for electricity arising from the emanations is only an apparent one arising from convection by means of the cloudy oxidization products. The conductivity arises from the phosphoric acids.—*Ann. der Physik*, No. 4, 1903, pp. 704–729. J. T.

5. *The Position of Radium in the Periodic System.* — R. Runge and J. Precht have obtained, by means of the bromide prepared by Herr Giesel, a more perfect spectrum than has hitherto been obtained. It was found that the strongest lines of radium are exactly analogous to the strongest lines of barium and the corresponding lines of the related elements Mg,Ca,Sr. From the behavior of radium vapor in a magnetic field radium is also to be classed with the above elements. The authors call attention to the following conclusions: "In each group of chemically related elements the atomic weight varies as some power of the distance apart of the two lines of a pair"; secondly, "The logarithms of the atomic weights and those of the distances when plotted as coördinates lie on a straight line for a chemically related group of elements." The atomic weight of radium is given as 257·8.—*Physikalische Zeitschrift*, 4 Jahrgang, No. 10, pp. 285–287. J. T.

6. *Charge on the Ion, produced in air by Roentgen Rays.*—Harold A. Wilson made a fresh determination of this quantity, after Professor J. J. Thomson's first determinations, and arrived at a result which was half as large as Professor Thomson's. The latter lately has revised his earlier determination and has obtained the same result as Mr. Wilson.—*Phil. Mag.*, April, 1903, pp. 429–441. J. T.

7. *Reversed Lines of Metallic Vapor produced in Narrow Capillaries of Glass or Quartz.*—When terminals of different metals are enclosed in narrow capillaries of quartz or glass one centimeter apart, an interesting series of reactions are obtained with powerful condenser discharges. The easily vaporized metals like cadmium, lead, tin, give both bright and reversed lines. The lines of these metals, which are linear and narrow in the spark spectra in air, broaden out in rarified hydrogen or rarified oxygen to a great extent, depending on the exhaustion and the energy of the discharge. In some cases this broadening is greater toward the red end of the spectrum. No spectrum of iron lines could be obtained in such capillaries: even when the terminals were only three millimeters apart, and the bore of the capillary was one millimeter and a half. Aluminum, however, gave its peculiar spectrum with certain lines reversed. —*Jefferson Physical Laboratory.* J. T.

II. Geology and Natural History.

1. *New Mineral Names.* Brunsvigite, a new Leptochlorite from the Radauthal; J. Fromme. Brunsvigite is found in the gabbro quarry, "Bärenstein IV" on the Schmalenberg in a vein with calcite, quartz, arsenopyrite, chalcopyrite, pyrite, galena and sphalerite. It occurs as thick to fine-leaved masses between the other minerals and also as rounded aggregates in the cavities. Its color is green to dark leek-green and has a gray-green streak. $H = 1 - 2$; $G. = 3{\cdot}0106$. The powder is easily decomposed by acids with the separation of pulverulent silica. The analysis gave the following formula; $6SiO_2$, $2Al_2O_3$, $6FeO$, $3MgO$, $8H_2O$. —*Min. u. petr. Mitth. 21, 1902, p. 171–177.*

Pyknochlorite, a new chlorite belonging to the clinochlore group. J. Fromme. In the gabbro quarry, "Bärenstein II" on the Schmalenberg occurs a vein formed chiefly of calcite intergrown with quartz. In the interstices between the minerals and binding them together occurs a new chlorite mineral which has been named pyknochlorite. It forms beautiful gray-green solid or micro-crystalline masses. Hardness $= 1 - 2$, specific gravity $=$ 2·8314. With acids only partially decomposed; before blowpipe yields a black slag. The analysis gives the following formula: $10SiO_2$, $4R_2O_3$, $17RO$, $14H_2O$; R^{III} being chiefly Al with a little Fe, R^{II} chiefly Fe and Mg with small amounts of Ca and Mn.—*Min. u. petr. Mitth. 22, 1903, p. 69.*

Liveingite, a new mineral from Binnenthal—R. H. Solly and H. Jackson. The analysis yielded: Pb, 47·58; S, 24·91; As, 26·93; from which the formula, $4PbS.3As_2S_3$ was derived. Liveingite is mon-clinic, $\beta = 89° \ 45\frac{1}{2}'$.—*Proc. Cambridge Phil. Soc. 1901, 11, 239.*

Serendibite, a new borosilicate from Ceylon—G. T. Prior and A. K. Coomáraswámy. This new species was found near Kandy, Ceylon, in the contact zones between an acid granulite and thin limestone bands. It occurs for the most part in irregular grains of a blue color. Luster is vitreous; fracture, subconchoidal; hardness, $6\frac{3}{4}$; density, 3·42; biaxial, probably triclinic; pleochroism from yellow to blue. The mineral is infusible, unattacked by acids, gives a little water when heated in the closed tube, and when fused with acid potassium sulphate and calcium fluoride gives the green flame of boron. The formula derived from the analysis is: 10 (Fe,Ca,Mg)O, $5Al_2O_3$, $6SiO_2$, B_2O_3.—*The Min. Mag., xiii, p. 224.* W. E. F.

2. *Les Richesse Minérales de L'Afrique;* by L. De Launay. Paris, Ch. Beranger, 1903.—This book describes the ore deposits of Africa as they are known and developed at the present time. An outline of the general geology of the continent is given in the early part of the volume and then follow in order discussions of the gold, copper and iron deposits, to each of which a chapter is devoted. Other chapters deal with the occurrence of the various other metals, with the diamond mines, the phosphate,

salt, coal and petroleum deposits. The book is illustrated by many maps and geological sections. W. E. F.

3. *The Glacial Geology of New Jersey;* by R. D. Salisbury, assisted by H. B. Kümmel, C. E. Peet and G. N. Knapp. Geol. Survey of New Jersey. Vol. V, 782 pp., 66 pls., 102 figs— The New Jersey Survey (H. B. Kümmel, State Geologist) has issued a work on glacial geology which is of great educational value. Part I, on The Drift and the Glacial Period, is an ably written text-book on glaciation in general with illustrations taken from New Jersey. Part II treats of local details of glacial action and will be of direct educational and economic value to the people of the State.

4. *The Birds of North and Middle Americas;* by Robert Ridgway. Part II, Bulletin U. S. National Museum, No. 50. 8vo, 834 pp., 22 plates.—This is a careful and elaborate revision of the families of tanagers, troupials, honey-creepers, and wood-warblers, with analytical keys, descriptions, and synonymy of all the species and subspecies. A. E. V.

5. *A List of North American Lepidoptera and Key to the Literature;* by H. G. Dyar. Bull. U. S. Nat. Mus., No. 52, 723 pp., 1902.—This extensive catalogue includes all the species described, up to date. The serial numbers of the species run up to 6,622, but there are some interpolated. The general distribution and principal synonyms are given. The work gives evidence of an immense amount of careful work, and will be indispensable for all entomologists interested in Lepidoptera. A. E. V.

6. *Synopsis of the Family Veneridæ and of the North American Recent Species;* by W. H. Dall. Proc. U. S. Nat. Museum, xxvi, pp. 335–412, 5 plates.—This contains a careful revision of the genera, subgenera and sections of the Veneridæ, with many changes in the nomenclature, made in accordance with the modern revisions of the rules of nomenclature. A. E. V.

Obituary.

Professor Henry Barker Hill, director of the Chemical Laboratory of Harvard College, died on April 6 in his fifty-fourth year.

Dr. Albert Huntington Chester, professor of chemistry and mineralogy in Rutgers College, died April 13 in his sixtieth year.

Rear-Admiral George E. Belknap, retired, who in addition to eminent services in the navy was in charge of important hydrographic work and was at one time superintendent of the Naval Observatory, died on April 7, at the age of seventy-one years.

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[FOURTH SERIES.]

ART. XLII.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. WORTMAN.

[Continued from p. 414.]

Origin of the Primates.

IN any attempt at a consideration of the question of the origin of the Primates, we are met almost at the very threshold of our inquiry by such a lack of definite information as effectually to bar our progress, in so far, at least, as positive or decided results are concerned. The only course that is open to us at present is to reason by induction and analogy, but it may well be that this method will prove futile enough and furnish a very unsafe guide in threading our way across this unexplored waste in the knowledge of simian history.

The first question of importance to discuss in this connection is the probable location of the place of origin of the Primates, and just here some welcome facts come to our aid. From the abundant and well-attested records of paleobotany, we learn first of all that a tropical vegetation flourished within the Arctic Circle as late as the beginning of the Cretaceous, and for reasons which will be presently given it appears highly probable that this was one of the regions in which climatic environment first presented sufficiently favorable conditions for the beginnings of higher forms of plant life. In other words, it was probably the original home of the Angiosperms, or flowering plants. The existence of the higher types of Mammalia was manifestly impossible before the appearance of the necessary plants upon which they so largely depend for food, and I shall therefore assume the existence of a close and intimate relationship between the development of the one and the origin of the other.

Just what climatic conditions obtained in the polar regions prior to the Cretaceous, whether there were alternate periods of heat and cold with consequent glaciation, or whether the climate was uniformly tropical, are questions with which our present inquiry is not vitally concerned, for the reason that the origin of the higher forms of mammalian life can not be consistently placed at a much earlier date than the beginning of the Cretaceous.

Touching the question of former glacial epochs, however, it is proper to state that more recent geological investigations have shown the existence of boulders of great size and thickness, scratched and glacial-like, in beds of Permian and probably of Triassic age also, in Australia, New Zealand, South Africa, India, and presumably in South America. The wide-spread occurrence of these phenomena over the Southern Hemisphere would seem to be impossible of explanation on any hypothesis other than that of glaciation or a period of cold. Such facts have led many geologists to believe in the existence of successive or intermittent glacial epochs in the past. A fair estimate of present opinion on the subject may be gained from Dana's statement,* which is as follows: "Thus, throughout the earth's history since life began, the only cold epochs of which proof has been found occurred near or at the close of the Permian, at the close of the Triassic, and during the Glacial period. At the close of the Cretaceous, another epoch is suspected to have occurred, but without direct evidence."

With a few exceptions the evidence of glaciation in the Northern Hemisphere is confined almost exclusively to the Glacial epoch proper, and it is to be seriously doubted whether conclusive proof of wide-spread glacial action in any former period will ever be found. At all events we are not warranted in the belief that a frigid temperature overspread the Northern Hemisphere at any time between the Jurassic and the Tertiary. On the contrary, all the testimony which has yet been gathered from various available sources shows that there were slow and gradual changes of temperature from tropical, through all the stages of subtropical, warm temperate, temperate, cold temperate, subfrigid, and frigid, in the long interval between the Jurassic and the Glacial epochs.

The class of facts upon which we most largely depend for conclusions respecting the former climatic conditions in any region are furnished by the fossil remains of plants and animals imbedded in its strata. In order that evidence of this character may become available, we must assume two propositions: (1)

* Manual of Geology, 1894, p. 1027.

That the animals and plants lived and died in the vicinity where their fossil remains occur; and (2) that by comparison with their nearest living allies we may deduce some information respecting their habits. For example, we know that such plants as Palms, Cycads, and Tree-Ferns require a given mean temperature for their existence. Frost quickly destroys them and they rapidly disappear where much freezing takes place. Their northernmost limit is found, therefore, at or near the isothermal line separating a warm temperate from a subtropical temperature. Thus, while a few of the hardier forms may be distributed along the borders, the vast majority of the species inhabit the more central tropical and subtropical parts of the earth, where they form a conspicuous and characteristic feature of the flora.

If, therefore, the remains of such forms as Palms, Cycads, or Tree-Ferns occur as fossils in a given locality, we may conclude without fear of error that the temperature of such place could not have been below that which at present limits their distribution, yet it may at the same time have been tropical or subtropical. Some information regarding the latter condition may be had from the relative abundance of remains of such species. If very abundant and in considerable variety, a subtropical or tropical temperature rather than that bordering on a warm temperature would be indicated. In the same way, we may assume the presence of remains of certain species of extinct animals to be indicative of, and equally conclusive proof of, temperatures in which their nearest allies live at the present day.

With this understanding of the nature of the evidence upon which we must rely, I pass next to a brief review of the former distribution of the plants in the Northern Hemisphere, and shall begin with a consideration of the fossil floræ of the Arctic regions. Certain deposits in Greenland, near Disco Island, 70° 33′ N. Lat.—the Komé beds—have yielded a rich flora, which according to Heer, its describer, is strictly comparable with that of the Neocomian or Lower Cretaceous of Europe and America. It includes Ferns, Cycads, Conifers, and a single species of Angiosperm—a Poplar. Of the Ferns, the genus *Gleichenia*, now almost exclusively tropical in its distribution, is represented by fifteen species. There are also four genera of Cycads, with numerous species, whose nearest living representatives now inhabit the tropical and subtropical regions. Pines, Redwoods, and other Conifers, some closely related species to which are now found living in China and California, go to make up the list of the Gymnosperms. The Angiosperms, as far as we now know, are represented by the single genus and

species *Populus primœva*, which is probably the oldest Angiosperm thus far discovered.

In such distant localities within the Polar regions as Spitzbergen and Alaska are found deposits of nearly or quite the same age, and here the same or a closely allied flora occurs. The conclusion is therefore obvious that the climatic conditions by which this plant life was surrounded were not confined to a single locality and were not the result of local changes, but this evidence compels us to believe that they were widespread and general over the whole Arctic region during this period. The mean temperature indicated by these plants, according to Heer,* than whom no better authority could be quoted, was from 21° to 22° C., or 70° to 72° F. This brings it very near the isothermal line 74° F., which separates the subtropical from the tropical temperature; hence the climate may be said to have been virtually tropical.

Deposits corresponding closely in age to that of the Upper Cretaceous of Europe and North America are found in the same latitude, near the same locality as that just described. These beds—the Atané—have furnished the remains of a flora no less remarkable than that of the Lower Cretaceous. In all, sixty-five species have been identified, of which fifteen are Ferns, two Cycads, eleven Conifers, three Monocotyledons, and thirty-four Dicotyledons. Of the Ferns, one is a Tree-Fern, which, with the Cycads and other species, at once gives a subtropical aspect to the flora. The Dicotyledons include such types as the Poplars, Bayberry and Sweet Fern, Fig, Sassafras, Heath, Cinnamon, Persimmon, Aralia or Ginseng, Magnolia, Myrtle, and Legumes. The living representatives of many of these species are now found in a subtropical or warm temperate climate, and if such evidence has any value it furnishes incontestable proof that the temperature of the Arctic regions, although still tropical, had suffered a decline from that of the Lower Cretaceous during the latter part of the period.

Turning next to the Tertiary, we find from the same class of evidence that wide-spread changes in the climatic conditions had occurred. There are deposits at many localities within the Arctic regions in which plant remains of this epoch are found, but their exact equivalents among European and American beds are difficult of determination. They were referred by Heer to the Miocene, but Dawson expressed the opinion that they were at least in part Eocene in age—a view which is more likely the correct one. Further exploration and the discovery of animal remains are necessary before these matters can be finally cleared up. At all events, it is perfectly

* See Professor Heer's famous work, Flora Fossilis Arctica.

certain that they are later in age than those containing the Upper Cretaceous flora above described.

As Wallace gives such an excellent summary of what is known on this subject, I quote his statement in full. He says:* "One of the most startling and important of the scientific discoveries of the last forty years has been that of the relics of a luxuriant flora in the various parts of the Arctic regions. It is a discovery that was totally unexpected and is even now considered by many men of science to be completely unintelligible; but it is so thoroughly established, and it has such a direct and important bearing on the subjects we are discussing in the present volume, that it is necessary to lay a tolerably complete outline of the facts before our readers.

"The Miocene flora of temperate Europe was very like that of Eastern Asia, Japan, and the warmer part of Eastern North America of the present day. It is very richly represented in Switzerland by well preserved fossil remains, and after a close comparison with the flora of other countries Professor Heer concludes that the Swiss Lower Miocene flora indicates a climate corresponding to that of Louisiana, North Africa, and South China, while the Upper Miocene climate of the same country would correspond to that of the south of Spain, Southern Japan, and Georgia (U. S. of America). Of this latter flora, found chiefly at Œningen in the northern extremity of Switzerland, 465 species are known, of which 166 species are trees or shrubs, half of them being evergreens. They comprise sequoias like the Californian giant trees, camphor-trees, cinnamons, sassafras, bignonias, cassias, gleditschias, tulip-trees, and many other American genera, together with maples, ashes, planes, oaks, poplars, and other familiar European trees represented by a variety of extinct species. If now we go to the west coast of Greenland in 70° N. Lat. we find abundant remains of a flora of the same general type as that of Œningen but of a more northern character. We have a sequoia identical with one of the species found at Œningen, a chestnut, salisburia, liquidambar, sassafras, and even a magnolia. We have also seven species of oaks, two planes, two vines, three beeches, four poplars, two willows, a walnut, a plum, and several shrubs supposed to be evergreens; altogether 137 species, mostly well and abundantly preserved!

"But even further north in Spitzbergen, in 78° and 79° N. Lat. and one of the most barren and inhospitable regions on the globe, an almost equally rich fossil flora has been discovered including several of the Greenland species, and others peculiar, but mostly of the same genera. There seem to be no evergreens here except coniferæ, one of which is identical with the

*Island Life, 1892, p. 183.

swamp-cypress *(Taxodium distichum)* now found living in the Southern United States! There are also eleven pines, two Libocedrus, two sequoias, with oaks, poplars, birches, planes, limes, a hazel, an ash, and a walnut; also water-lilies, pondweeds and an iris—altogether about a hundred species of flowering plants. Even in Grinnell Land, within 8¼ degrees of the pole, a similar flora existed, twenty-five species of fossil plants having been collected by the last Arctic expedition, of which eighteen are identical with the species from other Arctic localities. This flora comprised poplars, birches, hazels, elms, viburnums, and eight species of conifers, including the swamp cypress and the Norway spruce *(Pinus abies)*, which last does not now extend beyond 69½° N.

"Fossil plants closely resembling those just mentioned have been found at many other Arctic localities, especially in Iceland, on the Mackenzie River in 65° N. Lat. and in Alaska."

Thus it will be seen that proof in favor of the view that the Arctic regions enjoyed a mild and equable climate unbroken by periods of cold, up to and including the middle of the Tertiary, is simply incontestable and overwhelming. At the same time it is equally evident that while capable of supporting a luxuriant vegetation up to this period, the temperature, as indicated by the fossil plants, shows unmistakable signs of a slow and steady decline from a tropical to a temperate condition.

Let us next examine the evidence afforded by the plants as indicative of former climatic conditions in the regions now embraced within the North Temperate zone. Roughly speaking, we now transfer our attention some two thousand miles to the southward of these more typical localities in Greenland which have furnished the remains of the remarkable flora here discussed. Owing to more favorable circumstances and better facilities, the deposits in these latitudes have been much more extensively and thoroughly examined and their fossil contents more carefully collected and studied, than those of the Arctic regions. Moreover, we have in these deposits the remains of large numbers of extinct animals often associated with those of the plants, so that we are enabled to get a somewhat clearer idea of its ancient physical conditions. But in attempting to correlate the results of investigation obtained in one region with those in another, we have constantly to bear in mind the difficulties which beset the problem of establishing equivalency in the time scale in deposits of widely separated localities. We are accustomed to depend very largely, if not solely, upon the fossil contents of any two given strata for our ideas respecting their equivalency in age. It has no doubt often happened, however, that certain types of plants or animals originating in

one region were gradually distributed to others by migration, so that the deposits containing them would show the same or closely allied species in practically the same stages of development; yet this similarity in the contained fossils may not of necessity imply absolute synchronism of deposit, since a certain length of time must have been reqnired for the migration, which would have been longer or shorter in proportion as the distance was great or small and the obstacles to be overcome were easy or difficult. It is just such complications as these that arise when we compare the deposits of the Arctic with those of the Temperate latitudes, and prevent a final and absolute determination of their exact equivalency.

In the North Temperate regions, the Mesozoic strata reach a high degree of development and in many places contain rich deposits of fossils. In Europe, the Triassic and Jurassic are much better developed than in America, while on the other hand the Cretaceous series is much more varied and extensive in America than in Europe.

The Jurassic of Europe has furnished a flora consisting of Conifers, Cycads, Ferns, Equiseta, and two Monocotyledons. In all, there are some one hundred and fifty species, of which over eighty are Ferns, twenty are Conifers, and thirty or forty are Cycads. The Conifers are represented by genera and species closely allied to the Yew, Pine, Arbor-Vitæ, Cypress, and Norfolk Island Pine. The two Monocotyledons are said to belong to the Arum and Pandanus families, or such types in our living flora as the Calla, Skunk Cabbage, and the Screw Pine. There are no Dicotyledons or higher Angiosperms known with certainty.

In America, the flora of the Jurassic is not so well represented, but the known species have a close relationship with those of the Jurassic of Europe. Thus, Conifers, Cycads, and Ferns are the only forms yet brought to light. The American Jura has hitherto furnished no Monocotyledons, and as in Europe, the Dicotyledons are completely absent. According to all authorities, the climatic conditions indicated by this flora, as well as by the associated animals, both Invertebrates and Vertebrates, are such as are now found in the vicinity of the Equator.

The Lower Cretaceous of Europe is well developed and in many places is capable of division into a number of substages. In England, the deposits belonging in this series are the Wealden, Lower Greensand or Aptian, and the Gault or Albian. In Portugal, at least six divisions are recognized, which correspond almost exactly with the subdivisions of the Potomac formation on the Atlantic border in this country. The flora of the Wealden, according to Ward, contains eighty species,

which include two Algæ, two Fucoids, one Hepatic, one Chara, three Equiseta, twenty-three Ferns, twenty-one Cycads, twenty-four Conifers, and one Monocotyledon. It is remarkable for the entire absence of Dicotyledons. The lowermost Cretaceous beds of Portugal, which are considered to be equivalent in age to the Wealden, have, according to the same authority, yielded two Algæ, two Hepatics, three Lycopods, two Equiseta, seventy-nine Ferns, fifteen Cycads, twenty-nine Conifers, sixteen Monocotyledons, forty-seven Dicotyledons, five anomalous types classified as Proangiosperms, and three forms of uncertain reference. In like manner, the Potomac formation of America contains Ferns, Cycads, Conifers, Monocotyledons, and Dicotyledons, in nearly the same proportion as the beds of Portugal. The character of this flora gives unmistakable evidence of a tropical climate, and while we are not able to say whether the temperature was actually higher than in Greenland during the deposition of the beds supposed to be of the same age, we may feel perfectly certain that tropical conditions were wide-spread over the Northern Hemisphere during the early part of the Cretaceous.

In the basal strata of the Lower Cretaceous, no remains of true Dicotyledons have as yet been found. Higher up in the series they occur sparingly, but toward the top of the section they suddenly appear in great numbers and variety. Thus, in the Gault of England and in beds of corresponding age in Portugal are found the leaves of Poplar, Magnolia, Myrtle, Willow, Walnut, Maple, Sassafras, Fig, Cinnamon, Holly, Oak, Redwood, and Palms. In America, in beds of approximately, if not identically, the same age, occur Sassafras, Tulip-Tree, Magnolia, Aralia, Cinnamon, Poplar, Willow, Maple, Birch, Chestnut, Alder, Beech, Elm, Sequoias, and Palms, the leaves of some of the latter being ten feet in diameter. The leaves of a few Cycads are present, but they are not so abundant as they were in the lower stages, and here represent a waning group.

In a survey of this flora as a whole, together with a consideration of the manner of occurrence of certain of its constituent elements, two facts of more than ordinary importance force themselves upon the attention of the investigator: (1) There is an astonishing similarity or striking resemblance between these Cretaceous plants of Europe and America; and (2) the higher Angiosperms appear in identically the same manner in these two widely separated areas, by sudden introduction as if by impulses or waves of migration.

In regard to the first of these propositions, Ward in his excellent paper has shown that the early Cretaceous floræ of

the two continents are very similar. He says,* "We should not, of course, expect the species to be common to any great extent, and the comparison is practically limited to the genera. Looked at from this point of view, we see that the resemblance is indeed close, a great number of the important genera occurring in both floras. There are no less than 46 of these common to the two, though in some cases the author's individuality is probably alone responsible for slight differences in the terminations in the names." What is here said of the plant remains from the lower beds is also true of those from the Cenomanian, and in fact the entire Cretaceous flora of the two Hemispheres is strikingly similar.

The second fact of unusual importance is the sudden introduction of the higher Angiosperms in the several strata in which they occur. They first make their appearance in beds below the Cenomanian, but with very few exceptions these species are all strictly representatives of, and belong to, the higher forms. They exhibit few traces of a lower organization, and certainly fall far short of the connecting forms we should expect to find bridging the gap between the Dicotyledons and lower types, if their evolution had taken place in the regions where their remains are now found. It is possible to explain the sudden influx of so extensive, varied, and highly organized a flora as that of the Cenomanian only on the hypothesis of migration, and this migration was, moreover, in all probability due to a climatic change which permitted the species to spread into new localities formerly unfitted for their maintenance. There is no other way in which to account for the remarkable similarity between the floræ of the two Hemispheres, it seems to me, than to assume the existence of a common center of dispersion. All the facts in connection with the distribution of these higher plants offer such a striking analogy to a similar class of facts concerning the higher Mammalia, that I shall have occasion to recur to this subject again.

In the Upper Cretaceous beds of both Europe and America, the remains of a rich flora have been found. I can not better illustrate the character of this flora in America than to quote a few extracts from the work of Professor L. F. Ward, one of the most eminent authorities on paleobotany in America. In describing the types of the Laramie flora, he says,† in speaking of the genus *Ficus:* "Among my Fort Union specimens I have thus far found three species referable to that genus which, if this reference is sustained, and if no others be detected, will show that a climate existed in the Fort Union epoch and at

* Some Analogies in the Lower Cretaceous of Europe and America. Sixteenth Ann. Rept. U. S. Geol. Surv., p. 534, 1895.

† Bull. U. S. Geol. Surv., No. 37, 1887.

the latitude of Glendive [Montana] warm enough and moist enough to permit these chiefly tropical plants to thrive." Again, in speaking of the genus *Cinnamomum*, he says: "An almost exclusively tropical genus embracing about fifty species, confined to the Old World, but ranging on both sides of the equator. Fossil representatives are abundant in the Tertiaries of Europe, especially in the Eocene, but forms are reported as low as the Cenomanian. The four species of the Laramie thus far described argue a warm climate." And again, he says of *Zizyphus*, a genus related to the Buckthorn: "A widely distributed tropical and subtropical genus containing in the present flora about fifty species. It has been hitherto represented by eight Eocene, one Green River and five Laramie species, none of the last being from the Fort Union strata." He describes three species from the Upper Cretaceous of Montana. In like manner he mentions a number of other types of a tropical or subtropical habit from the Laramie, or Upper Cretaceous beds. Lastly, I may mention the presence of Palms of the genus *Sabal*, recently described by Hatcher as an absolutely conclusive piece of evidence in favor of a Floridian climate during this epoch, as far north as Wyoming and Montana.

In the Tertiary, a subtropical climate continued in America as far north as central Wyoming, to near the close of the Eocene. This is proved by abundant remains of Palms in the Green River shale beds, and by the presence of numerous tropical species of Vertebrates and Invertebrates in the Bridger beds. Before the close of the Eocene, however, the temperature in this latitude underwent a change, and by the time the Oligocene is reached a strictly temperate climate had appeared. In Europe, similar changes in the climatic conditions throughout the Tertiary, from an almost, if not quite, tropical temperature through all the intermediate stages to that of a frigid temperature in Glacial time, are to be met with.

Viewed from the standpoint of the fossil plants, therefore, the contention that the Northern Hemisphere has passed through all these phases of climate from torrid to frigid, from early in the Mesozoic to the present, is simply incontestable. The evidence is equally conclusive that the cooling-off process was inaugurated at the Pole and gradually extended to the southward. The assumption, moreover, that the higher Angiosperms originated and were evolved in the more southern latitudes, where they so suddenly appear, is illogical and untenable, not only by reason of the virtual absence of any ancestral forms foreshadowing or leading up to them in the floræ of the older epochs, but by the sudden appearance of the same or closely allied types in identically the same manner and, as far as we

know, at the same time, in localities so widely separated as Europe and America.

If, now, we examine these problems from the standpoint of the distribution of the ancient mammalian faunæ in the Northern Hemisphere, we reach conclusions so strikingly similar, that the two classes of facts taken together constitute such a basis or groundwork of probability, that we may feel reasonably safe in locating the place of origin of both the higher plants and certain mammals, at least, within the polar regions.*

The facts of mammalian distribution in the Northern Hemisphere may be briefly stated as follows: Early in the Mesozoic, there appeared small mammal-like forms, which were widely distributed over both the Northern and Southern Hemispheres. Representatives of these species continued throughout the Cretaceous, and finally disappeared in the early stages of the Tertiary. From these forms the modern Marsupials undoubtedly had their origin. Many of them are classified in the group Multituberculata, which without much doubt finds its nearest living representative in the Duckbill of Australia. It should be here stated that with very few exceptions all these forms are represented by fragments of jaws and teeth. In one instance, however, a fairly complete skull is known (*Tritylodon*) from the Karoo beds of South Africa. The teeth of this species are astonishingly like those of many types in the Northern Hemisphere, and hitherto it has always been classified in this group. Seeley has shown that the organization of the skull presents so many reptilian characters as to cause him to refer it to the Reptilia. If this reference is correct, then in the absence of any facts to the contrary it is highly probable that all the Multituberculates are as much reptile as mammal. Indeed, it is not easy to say at first glance upon which side of the line living Monotremes should be placed. There can be little doubt that, when more fully known, these ancient fossil types will present every conceivable gradation between these two great divisions of the Vertebrata.

One fact in connection with these Mesozoic forms stands out clearly and distinctly, and that is that as far as we are permitted to judge from their fragmentary remains, the progress of their evolution toward any of the higher mammals was very slow indeed. The amount of change registered by their teeth throughout the greater part of the Mesozoic is comparatively insignificant. On this account it is inconceivable that any of the species with which we are at present acquainted should be regarded in the light of ancestors of the higher types, or Eutherian Mammalia.

* Some very noted botanists have held this view of the origin of the Angiosperms within the polar regions; thus Gray, Saporta, and Nathorst were convinced of its truth, and Dawson thought it probable.

The oldest Tertiary strata containing mammalian remains which are at present known are found in the San Juan Basin of New Mexico, and were named by Cope the Puerco. These beds are from five hundred to eight hundred feet in thickness, and apparently lie conformably upon the Laramie, or Upper Cretaceous. Within the lower fifty feet are found the remains of a rich mammalian fauna, thirty-one species in all, composed largely of representatives of the higher, or Eutherian, subclass. Associated with them are five species of Mesozoic types closely related to forms from the older Laramie beds.

In this same region, at a distance of from five to eight hundred feet above the Puerco layer, occurs a second fossil-bearing horizon, which I have called the Torrejon stage. From this bed, forty-four species have been identified, of which five are of the Mesozoic type. The facies of the fauna is very like that of the Puerco, and there are many genera or their derivatives common to the two horizons, but the species are in every case different. Just as the Eutherian mammals in the Puerco bed below were all of sudden introduction, so there were no less than twelve genera which represent entirely new and previously unknown types.

Resting conformably upon the Torrejon comes the Wasatch, the beginning of what we may call the middle division of the Eocene, and here again is a rich mammalian fauna. Deposits of this age are found in the Big Horn, Green River, and Wind River Basins of Wyoming and all have yielded many remains of extinct mammals. Like that of the preceding bed, the fauna of the Wasatch is made up of two elements: One which includes the modified descendants of the older preëxisting types, and another which is entirely new to the region. This latter element in the Wasatch comprises not only new genera and species, but entire new orders. Thus, we meet for the first time with such types as the Rodentia, Artiodactyla, Perissodactyla, besides whole suborders and families included in the Carnivora, Amblypoda, Primates, and Insectivora. Some of these types continue through several subsequent stages and then disappear, while others become the dominant factors in the succeeding development and finally give rise to the modern mammalian fauna. What is here said of the Puerco, Torrejon, and Wasatch, is likewise true of the Wind River, Bridger, and Uinta of the Eocene. New and strange forms constantly appear, of which no vestige nor trace has ever been found in the older beds. Nor is this sudden introduction of new types confined to the Eocene, but is equally true of the Oligocene, Miocene, and Pliocene beds of this country.

The most remarkable circumstance connected with the facts here enumerated is that identically the same thing happened in

the Tertiary deposits of Europe. The succession of these strata is not so complete in Europe as in America, and their record of the appearance and disappearance of mammalian forms is less perfect; however, it is sufficiently complete to give the broad features of mammalian succession. While the Jurassic mammals are well represented, and correspond closely genus for genus with those from the Wyoming beds in America, the Cretaceous forms as well as those corresponding to our Puerco have not been found in Europe. The oldest Tertiary beds in Europe from which mammalian remains have been obtained are those at Cernay in France. According to Osborn,* this fauna bears a close resemblance and corresponds to that of our Torrejon. It is in the succeeding Wasatch or its near equivalents, however, that the most striking similarity occurs. Exposures of beds of this age are found at many localities in Europe, and a fauna almost equal in richness and variety to that of America is known. Just as in America, the sudden introduction of the same entire orders—the true Primates, the Rodentia, Artiodactyla, Perissodactyla, Insectivora, as well as many suborders, families, and genera of the various other groups—takes place without previous warning. The most remarkable fact is the similarity observable in the two faunæ. In many instances, the species belong to the same genera which are common to the two Hemispheres.† In the following succession, the introduction of new types of the same general character as those in America proceeds in the same sudden and unheralded manner.

Now, what is the significance of these facts and from what source or sources were these faunæ derived? In the case of the Puerco, we have the sudden introduction of thirty or more species belonging mostly to a group of mammals hitherto entirely unknown upon the earth. The species of the Mesozoic types may be accounted for by derivation from the preëxisting mammals whose remains are found in the underlying Cretaceous, but as regards the Eutherian element of the fauna, no earlier traces of it have ever been found, and he who would maintain that this new Eutherian element in the Puerco fauna developed from any of the known Cretaceous forms, in the ordinary course of evolution, would be so utterly lacking in a proper sense of morphological proportion as to be a very unsafe guide in such matters. The Laramie or Upper Creta-

* A Review of the Cernaysian Mammalia, Proc. Phila. Acad., 1890.

† The more important of the nearly related or identical genera common to Europe and America in the Wasatch or its near equivalent in Europe, thus far identified, are *Coryphodon*, *Phenacodus*, *Hyracotherium*, *Pantolestes ?*, *Paramys* and *Plesiarctomys*, *Heptodon* and *Lophiodon*, *Arctocyon* and *Anacodon*, *Palæonictis*, *Sinopa* and *Proviverra*, *Oxyæna*, *Calamodon*, *Hyopsodus*, and others.

ceous beds are extensively exposed in the same region in which the Puerco fossils are found, and indeed the remains of many characteristic Laramie land Vertebrates occur in the strata immediately underlying those containing the Puerco, but notwithstanding the most careful and extensive search, which I have myself conducted, not a vestige of the Puerco forms has ever been found in these underlying beds. The same is true of the vast stretch of territory along the skirts of the Rocky Mountain divide in which the Laramie is so extensively exposed. Not a tooth, not a scrap nor a fragment of a bone referable to these Puerco Eutherians has ever been found, in spite of the fact that many of the most expert collectors have searched for them assiduously in these localities for many years. It is hardly possible to explain their absence from the Cretaceous on the basis of unfavorable conditions of preservation, for the reason that we have not only the remains of many species of land Vertebrates well and abundantly preserved, but we have Mesozoic mammalian remains as well. The only explanation which seems to me possible is that they were migrants coming into these latitudes for the first time at the beginning of the Puerco.

The same argument applies with equal force to the new elements which were introduced in the Torrejon, Wasatch, Wind River, Bridger, and other epochs. They were simply new-comers representing so many waves or impulses of migration, and the fact that practically the same species were introduced at practically the same time, in the same order, and in the same abrupt manner, in two such widely separated localities as the Eastern and Western Hemispheres, adds overwhelming proof that the two faunæ had a common center of dispersion.

Now, where is it possible to locate such a land area common to the two Hemispheres? Geologists have made out a sufficiently complete history of the continental land masses, as well as of the great ocean basins, to give a tolerably exact idea of the main facts. All are agreed that at no time, at least from the beginning of the Mesozoic to the present, were the broad relations between the oceans and continents, either to the east, west, or south of the localities under consideration, materially different from what they are to-day. There is no evidence whatever of any land connection between the two Hemispheres at or near the Equator at any time in the past, so that the only possible place where this common land area could have existed was in the North.

Let us examine the question again, from the standpoint of the faunal changes which are indicated in the successive deposits of our American Tertiaries. In the Wind River and

Bridger epochs, the general facies of the fauna and flora is that of a tropical or semitropical region, as everyone who has given any attention to the subject is bound to admit. Palms, tropical Invertebrates, Alligators, tropical Turtles, and numerous species of monkeys, give ample proof of the nature of a climate which is to-day so necessary to their existence. In the succeeding Uinta, deposits were made within less than fifty miles to the southward of the typical Bridger localities, and in them we find but few fragments of these tropical or semitropical conditions remaining. The general aspect of the fauna gives evidence of a warm temperate climate, with the appearance of extensive savannas and much open country. In the Oligocene deposits of nearly the same latitude, with the exception of a single specimen of Alligator, no traces of any remains referable to, or characteristic of, even a semitropical climate have been found, notwithstanding the fact that these deposits are among the richest in mammalian remains of any in the world, and have been most thoroughly explored. The monkeys, Palms, tropical Turtles, and Invertebrates had completely disappeared, and there is overwhelming proof to the effect that they migrated to the southward. The European Tertiaries contain the same record, and the evidence that a general southward retreat of both the higher plants and mammals was in progress throughout much of the Cretaceous and the whole of the Tertiary is so complete, conclusive, and incontestable, that it may, in my judgment, be accepted as a fully demonstrated fact.

If, therefore, the sudden introduction of these new elements into the succeeding faunæ and floræ is to be explained upon the basis of migration, we are then in a position to assign a rational cause for its occurrence. We have already seen that the temperature in the region of the Pole was tropical in the early Cretaceous, and that it slowly declined throughout the succeeding epochs until finally a frigid condition was established. The migration of the Puerco fauna we may readily believe to have been caused by the appearance of unfavorable conditions, both climatic and vegetal, which gradually supervened within the limits of its ancient boreal home. In like manner, further modifications of the climate and vegetation in the same region caused the Wasatch exodus, and, like their Puerco predecessors, they had no alternative other than to follow the receding tropical forests to the southward. That some of them remained behind and were gradually modified to fit the new and changing environment, however, there can be also very little question. In this manner and from this cause doubtless arose those types which came finally to dwell in temperate and arctic climates. When changed conditions in the environment

arose, the inhabitants of the region had choice of one of three alternatives; migration, modification to fit the new conditions, or extinction. And I may add that paleontological study concerns itself almost exclusively with deciphering the record of the successes and failures of animal species along these lines.

In the case of the Primates, their structure at the beginning of the Wasatch had been fully adapted to an arboreal existence, as their prehensile extremities so fully demonstrate. Being exclusively dependent on these conditions, they were bound to follow in whatever direction the limits of the tropical forests shifted; and that the recession and gradual retreat of these forests was from within the Arctic Circle in the North to the vicinity of its present confines in the South, during the interval between the Middle Cretaceous and the Glacial epoch, is supported by an overwhelming abundance of evidence. It thus becomes possible, it seems to me, to locate the place of the origin of a large number of the higher Mammalia. Whether a similar series of changes took place at the South Pole, giving rise to its own peculiar types of mammals, is as yet uncertain, but at the same time not improbable. At all events, the Primates belong to the North, and it is within the Arctic Circle that they had their beginning. *

The second inquiry with which we are at present concerned is the kind and character of mammal from which the Primates were probably derived. Unfortunately the evidence necessary for a final solution of this problem is very far from complete. The question of the oldest known Primates has not yet been settled with satisfaction. Certain species from the lower Tertiaries of this country, notably the Puerco and Torrejon beds, have been variously referred to the Primates and Creodonta by investigators who have studied them—Cope, Scott, Osborn, Earle, and Matthew. These animals are known almost exclusively from the teeth, and in a few instances only are any of the

* In this connection I wish to call attention to the admirable work of Hon. G. Hilton Scribner, New York, 1888, "Where did Life Begin?" It is now quite impossible to state by whom this view was first entertained, but the late Professor Asa Gray, in a private letter to Mr. Scribner in 1884, distinctly claimed the credit of having been the author of the migration on north and south lines. Reference to Gray's published writings, however, as well as to those of Saporta, Nathorst, and Dawson, fails to show that any attempt was ever made by any of these eminent investigators to put forward the proofs and formulate the view into a distinct hypothesis of the Polar origin of life. In this Mr. Scribner was clearly the first, and so ably and logically was the Polar Origin theory presented, that Dr. Gray in commenting upon it was led to remark that Mr. Scribner's position was "simply incontestable." In the light of the great mass of evidence now at hand, it is easy to recognize and to appreciate fully the extreme probability of such a view; but when we recall the almost total lack of evidence in its favor at the time Mr. Scribner's book appeared, his work becomes all the more noteworthy, and in my judgment is entitled to a high rank among intellectual performances of a similar kind. This should thus be known as the Scribnerian Theory of the place of the origin of life.

other skeletal parts represented. In comparison with the oldest and most primitive undisputed monkeys, a careful examination of these Puerco and Torrejon forms reveals a wide difference in the organization of the two, and it is much to be doubted whether they really have anything in common with the true Primates. It appears necessary, however, to make an exception to this statement in the case of the genus *Mixodectes* and possibly also of *Olbodotes*. Matthew believes,* from an associated astragalus, that the former of these genera belongs to the Rodentia rather than to the Primates, but its successors in both the Wasatch and the Bridger show very strong Primate affinities; hence, there can be little doubt that they constitute an aberrant side branch of the main Primate axis.

If we thus exclude the *Mixodectes-Microsyops* series, the oldest remains of true and undisputed Primates occur in the Wasatch, and there are excellent reasons for the belief that they were new types of sudden introduction in the region, at the beginning of this epoch. Unfortunately, these Wasatch forms are very imperfectly known, so that it is not until we reach the Bridger that anything like complete skeletons have been obtained. Some, at least, of these Bridger types, while true monkeys, were in practically the same state of evolution as many of the existing lemurs, so that by careful comparison of the two groups we are enabled to eliminate the specialized and advanced features and reach the more fundamental primitive characters which must have belonged to the ancestors of all Primates.

There has been relatively little speculation on the definite and more exact origin of any of the great groups of Eutherian mammals, and apparently less on the Primates than any other. Huxley, in his famous paper "On the Application of the Laws of Evolution to the Arrangement of the Mammalia," expressed the opinion that they arose from a central type of the Insectivora, such as the Erinaceidæ. Nearly twenty years later we find no less an authority than Hubrecht† warmly supporting the same view. In speaking of *Erinaceus* and *Gymnura*, Huxley's exact words are: "in them, even more than other Insectivora, we possess the key to every peculiarity which is met with in the Primates, Carnivora, and the Ungulata." However much I may be disinclined to dissent from the views of so great a master in morphology, we can not disregard the fact that the very large increase in our knowledge of the extinct forms during the past twenty years has materially altered our conceptions of the relations of these groups. It is true that the Insectivora furnish

* Bull. Amer. Mus. Nat. Hist., 1897, p. 265.

† Descent of the Primates, p. 5, 1897.

a type of cerebral circulation which might easily have passed into that of the Anthropoidea, through the suppression and disappearance of the stapedial branch of the entocarotid; but, as we have already seen, this character is shared by the Rodentia and probably by other groups as well. At the same time it does not furnish a type of cerebral circulation from which that of the lemurs could have been evolved.

The greatest difficulty in the way of deriving the Primates from any form or forms of the Insectivora at present known consists in the total lack of prehensile powers of the manus or pes. Any group which is placed ancestral to the Primates must of necessity be one in which some distinct approach to this condition is made, since its possession is one of the chief requisites of fundamental importance. For this reason, if for no other, the modern types, at least, of the Insectivora, can not be looked upon as the forerunners of, or as more than very distantly related to, the ancestors of the Primates.

With the single exception of *Lophiomys* among the Rodentia, the only other living mammals which exhibit prehensile extremities are found among the Marsupials, and the evidence points very conclusively to the fact that all of them, even those with highly modified limbs for terrestrial progression (as the kangaroos), are descended from ancestors with grasping hands and feet. It is therefore not beyond legitimate supposition to assume the existence of a very considerable group of ancient Metatherians living within the Arctic Circle during Cretaceous time, whose manner of life had already become arboreal. If such a group did exist, it is far more likely that the Primates were derived from it rather than from the Insectivora or any other group now living. Future research and discovery in these regions will alone settle the correctness or incorrectness of this hypothesis, and until such discoveries are made we must be content with the results of speculation.

[To be continued.]

Art. XLIII.—*The Geological Structure of the Southwestern New England Region*; by William Herbert Hobbs.

Former Assumption of Deformation largely by Folding.

The southwestern New England region, by reason of its prominence in the early heated discussions upon the stratigraphic and dynamic problems of geology, has sometimes been designated "The Battlefield of American Geology." Its prominence in this controversy is to be explained chiefly on two grounds—its proximity to the early American colleges and the exceptional intricacy of the problems involved in its study. The first condition is responsible for the large number of geologists who figured in the Taconic Controversy; the second for the wide range of opinions expressed, for where little can be learned by observation much may be assumed, though not without challenge. It is certainly most unfortunate that the solution of the most fundamental problems of the science, in their application to America, should have been sought in a region which probably ranks with any yet known both in the intricacy and in the obscurity of its geological structure.

All work earlier than that of Dana may be to-day passed over as offering nothing of value upon the geological structure of the region. Charles Hitchcock and Ebenezer Emmons in Massachusetts did, indeed, prepare some careful sections across the western mountain ranges, and these sections fail to be of service to-day not from any lack of ability or of thoroughness on the part of the excellent observers, but because any work so limited and carried out upon ideas of rock structure which were current at the time is wholly inadequate. Percival's work in Connecticut was essentially areal mapping, and while his observations of petrographic characters and his correlation of exposures to form rock belts must challenge our admiration, he was yet too wise and too cautious to risk any dogmatic statements regarding the tectonic structure of the region. It is clear, however, that he believed the crystalline rocks to be given their present attitudes as the result of system of flexures.*

Dana by most careful work, chiefly areal, but in part structural also, extending throughout the area from Vermont to Long Island Sound in New England and in much of eastern New York, was able to solve many of the problems which had vexed the early school of geologists, even though he was too

* Percival, Geol. of Connecticut, New Haven, 1842, pp. 289–298.

deeply involved in the controversy to settle them. Walcott, by his discovery of fossils in beds hitherto supposed to be barren of them, was able to review the early questions of stratigraphy and to end forever the Taconic Controversy.

The problem of the areal delimitation of horizons within the New England area and the determination of the geological structure of the region remained, and the early dissensions had at least shown the necessity for a much more thorough survey of the region than any which had been attempted. The work of the U. S. Geological Survey within the region, begun before that of Dana had been completed, was therefore taken up with a plan more comprehensive than any other and on a scale more nearly what was demanded by the conditions of the problem.

In view of the difficulties which have been encountered in the progress of this work and the methods of investigation which experience has shown to be of value, it is well to consider for a moment the fundamental assumption of Dana in his study, and also the dominant idea maintained throughout all the earlier work of the U. S. Geological Survey. Dana in his later papers summarizes the general geological characteristics of the Taconic region and says of the structure:

"The rocks owe their positions to a system of flexures, and the folds are to a large extent overthrust folds."*

It is evident from his sections that it was not Dana's intention to express by the term "overthrust folds" ruptured folds, but folds with inclined axial planes. In his summary he makes no mention of faults, and though a fault is indicated in one or two of the sections, it is evident that faulting hardly figured in his conception of the structure of the region.

Essentially the same opinion was held by Pumpelly, who was in charge of the work of the U. S. Geological Survey during the earlier years, when the Hoosac-Greylock province in northwestern Massachusetts and southern Vermont was surveyed. With him, however, the supposed absence of faulting within the area was clearly expressed as the reason for assuming a deformation wholly by folding. In his report he says:

"It was evident that our first and hardest work would be to find the key to the structure of the region. For this purpose I sought a region where the western edge should present, instead of a straight line, as many bay-like curves as possible, and where the structure of the ridge itself should show folds with pitching axes. I hoped in such a region to eliminate the difficulties introduced by possible faults, as well as the temptation to infer their existence; and also, in the case of pitching folds, to get through

*James D. Dana; On Taconic rocks and stratigraphy, with a geological map of the Taconic region. This Journal (3), xxix, 209, 1885.

radiating cross sections a knowledge of the true order of bedding."*

There have been few geologists more thorough and conscientious than Raphael Pumpelly, and the realization of the danger of inferring faults is perhaps a characteristic of all the best American geologists of the recent past and of the present alike. It ought, however, to be pointed out that the danger of inferring faults where they are absent, is hardly more serious than that of assuming their absence where they are present. The present attitudes of the rock beds must be accounted for either by the one or the other kind of deformation or by the two in conjunction, and these attitudes can in most cases of difficult areal geology be accounted for upon either theory. It is also worth noting that the edge of a ridge which shows many "bay-like curves" is just the kind most likely to be caused by a series of parallel and intersecting faults; and the presence of folds with pitching axes, while offering a possible and perhaps adequate explanation for the alternation of formations in the direction of their strike, does not necessarily reveal the real or the only actual cause.

This assumption of the absence of faulting throughout the New England area has been fundamental and far-reaching in the work of the Survey, as is shown by the fact that in the area of 200 square miles mapped with great detail and described in the report cited, but a single fault is indicated, and this a strike fault, presumably an overthrust. As the work has been extended to the south the same tendency to resist the temptation to locate faults has been manifest, and from his own experience the writer can testify that in twelve seasons of independent field work, or until the Pomperaug Valley area of Newark rocks was examined, not a single normal fault was entered upon his maps. It is believed that the tendency has been hardly less marked in the work of other members of the division, and it might almost be added, for the most careful work upon the crystalline schists throughout the country. Indeed it would hardly be too much to say that structural studies of the crystalline areas of the United States, with the single exception of the Great Basin region, have been carried out upon the assumption that rock deformation takes place by one process only, namely, by crustal folding and the thrusts incident to folding. Even in the classical area of the Great Basin the attempt has recently been made, though unsuccessfully, to explain the structure by a system of folds alone. This marked trend in American geological work may be in no small measure due to the classical geological studies of the

*Pumpelly, Wolff, and Dale; Geology of the Green Mountains in Massachusetts. U. S. Geol. Survey, Mon. xxiii, 7, 1894.

Rogers brothers, who by their explanation of Appalachian structure on the basis of folding alone, not only established a new type which bears that name, but developed methods which have been left as a legacy to their successors.

In Europe, on the other hand, the principles so long ago worked out by Kjerulf, Sedgwick, De La Béche, John Phillips, and especially by Daubrée* have been utilized to such an extent that the recognition of systems of faults as important elements of crustal deformation may be truly said to be the most marked line of cleavage which separates European structural studies from American. It has been especially the work of Suess to correlate these scattered studies and to show that the lineaments of the continents are lines of normal faulting, between which great orographic blocks have been depressed by different amounts. His monumental work upon The Face of the Earth† has been the greatest interpretative work upon structural geology of the past quarter century, and marks an epoch in the history of the science. In the Principles of North American pre-Cambrian Geology, the most comprehensive American treatment of rock deformation, Van Hise devotes 75 pages to a consideration of deformation by folding, whereas 10 pages suffice for a treatment of jointing and faulting inclusive of thrust faults which are connected with folds. There is no doubt that the proportion of space thus devoted to joint and fault structure is far beyond what its consideration by American geologists would warrant.

Inadequacy of Hypothesis of Folding.

As respects the study of the southwestern New England area, it is, I believe, time to admit that the basal assumption of a deformation by folding alone, which has now been given a trial by the Survey during a period of nearly twenty years, has proven entirely inadequate. Where belts of limestone are present to serve as guides in the areal and structural work, the order of superposition of formations, and in a very general way the geological structure, have been made out with a reasonable degree of certainty. In the broad belt of schists and gneisses which lie to the eastward of the limestone, on the other hand, it has thus far been found impracticable to discover any structure regarding the presence or absence of which any two of the workers can agree. This is true in spite of the fact that the geologists in the field have acquired by long experience a familiarity with the varied petrographical types of the province and with the apparent structures developed in

* Daubrée, Géologie experimentale, pp. 304–306, Paris, 1879.
† Antlitz der Erde, two vols., Prag and Leipsic, 1885.

them, and are, moreover, by reason of the most cordial personal relations desirous of securing perfect harmony of view. From examination of himself, no less than of others, the writer is inclined to believe that confidence in any structure worked out in the region upon a doctrine of deformation by folding alone is more largely based upon psychological than upon geological conditions; and this for the reason that a feeling of confidence inspired by observation at one locality has too often been quickly and most effectually dispelled by the next succeeding observation at an adjacent exposure. In the study of the structure within the gneiss belts there are two main tendencies which in varying proportions will be found to characterize the work of different geologists. One tendency is to group together within a single formation a considerable number of variant types of gneiss because no apparently satisfactory basis for their separation is at hand; and as the work progresses it is found that all the types of one formation can be duplicated in the others. The other tendency is to make an elaborate differentiation of units on a petrographical basis, with the result that extreme difficulty is met with in accounting for the present attitudes of the rocks, and large drafts must be made upon the imagination. At different points between the two horns of the dilemma different workers will very naturally be ranged.

The Newark Areas in their Relation to the Crystalline Belts.

In the summer of 1899 the writer, in surveying for folio publication the areas for 30′ quadrangles, mapped with much detail the circumscribed area of Newark rocks lying within the basin of the Pomperaug River in Connecticut. These formations of the Newark system present markedly contrasted petrographical types, are practically unaffected by flexuring or metamorphism, but exhibit in the most beautiful manner the results of a deformation by jointing and normal faulting. After long attempts to decipher the obscure and illegible characters in the structure of the surrounding gneiss belt, the transition to the clearness and simplicity of the record preserved within the Newark basin was like the passage from darkness to light. The study of the Newark area showed that it was deformed by a complex system of parallel and intersecting faults all near the vertical, and that the system of joints which preceded and conditioned the system of faults was with little doubt the result of compressive stresses which affected the southwestern New England province as a whole. The principles underlying such a deformation by fracture as a result of compressive stress have been given a somewhat full exposi-

tion by Becker* and were extended and applied to the area in the writer's report upon it.† The greatest value of the investigation of this Newark area, as it relates to the structural problems involved in the study of the crystalline belt, has been to show that no adequate explanation can be offered for the present attitudes of the rocks within that belt which fails to take account of a deformation by normal faulting as well as by folding, for it would be absurd to suppose that the faults characteristic of the Newark areas are not extended beyond their margin. Indeed, the evidence that they pass far beyond these margins into the crystallines has been shown by their direction of the courses of streams.‡ A somewhat careful review of the studies made of the other Newark areas§ of the Piedmont plateau has shown that while systems of parallel joints and faults had not been generally recognized as such, with not an exception numerous intersecting faults of the normal type had in each area been observed, and all recent observers have further expressed the view that many other faults remained concealed. The obvious lesson from these considerations is that the deformation of the intervening areas of crystalline schists—and these areas are not large in proportion to the Newark basins—must be not only by folding and probably also by faulting in pre-Newark time, but there must have been superimposed upon the earlier structures the system of jointing and faulting of post-Newark time. It is probable that the throws along the faults of this system outside the Newark basins will in general not be as great as those within the basins, for the reason that the latter are depressed areas within the crystalline terrane, but it will hardly admit of doubt that they have been important enough to produce a mosaic of orographic blocks in which different beds will be placed in juxtaposition along essentially vertical walls at the present surface. Another result of the study of the Newark areas has been to confirm the views of some writers that displacements are seldom concentrated upon a single plane of faulting but are usually distributed over a number of parallel planes lying in a zone more or less extended. Such distributive faulting renders more difficult the observation of individual fault planes, and even when these are discovered it is apt to leave an erroneous impression of their relative importance.

* George F. Becker, Finite homogeneous strain, flow and rupture of rocks; Bull. Geol. Soc. Am., iv, 50, 1893.

† The Newark system of the Pomperaug valley, Connecticut, Twenty-first Annual Report of the Director of the U. S. Geological Survey, Part III, pp. 1-160.

‡ The river system of Connecticut; Jour. Geol., ix, pp. 469-484 (1901).

§ On the former extent of the Newark system; Bull. Geol. Soc. Am., xiii, pp. 139-148, 1902.

Methods of Investigation.

Convinced, then, of the presence of a system of faults within the crystalline belt, the writer's next problem was to determine, if possible, its relation to the system of joints, the direction of its component series of parallel faults, and the part which it has played in the deformation of the area. The difficulties in the way of reading at once the composite structure of folding and faulting in rocks so nearly of one petrographical type as are the gneisses of the region, seemed, in the absence of established methods, to be insuperable, and attention was therefore first directed to those parts of the area in which limestone occurred. In the search for evidence of the system of faults within these areas the most hopeful factor was that rectilinear surface elements are characteristic of joint and fault structures, which are in contrast with the curves characteristic of folding. To this was added the knowledge derived from study of the Newark areas that the post-Newark system of faults, at least, had not been affected by subsequent folding.

It may be stated that based upon this and other known peculiarities of faults, methods more or less decisive have been developed which have led to the determination of elements in the fault system of the region. These methods have been elsewhere described* and can be but briefly referred to here.

Some of the indications of faults are:

1. Beds formed at different times in juxtaposition along a plane transverse to their bedding.
2. Offsetting of formations in outcrop.
3. Offsetting of outcrops as definite topographic features.
4. Dikes.
5. Abrupt changes of strike and dip not indicated in the folds.
6. Fault breccias.
7. Slickensides.
8. Abrupt disappearance of outcrops along a markedly rectilinear boundary.
9. Occurrence of scarps in the more resistant rocks.
10. Fault gorges.
11. Arrangement of surface springs in rectilinear directions.

It was further realized that it would probably be difficult to locate more than a small proportion of the individual faults occurring within the district, and effort was therefore made as early as possible to learn the distinguishing characteristics—especially the bearings of the individual fault series—of the

*The Mapping of the Crystalline Schists, I, Methods; II, Basal Assumptions. Jour. Geol., x, pp. 780–792, 858–890, 1902.

fault system. Additional observations of value for determining the system of faults as a whole are:

1. The arrangement of rectilinear formation boundaries in a network of parallel series.
2. The arrangement of individual faults in intersecting parallel series.
3. Determination of the joint system and its relation to the fault system.
4. Zigzag topographic relief composed of straight elements in parallel series.
5. The drainage system a network of intersecting parallel series.

With abundant outcrops a fault system may be disclosed upon the areal map by the generally rectilinear or zigzag boundaries of formations. If not, some indication may be afforded by the prevalence of straight lines and sharp bends in the topography, particularly if the lines fall into intersecting parallel series. Such a relief may not be apparent without careful examination of the map, for the reason that the particular combination of directions is not known, and it may yet be quite striking when once discovered. Again, the drainage lines may compose a network which in direction conforms both to that of the topographic lines and that of the formation boundaries. The prominent joints observed at the individual exposures, as was long since shown by Daubrée, will, if of the same origin as the fault planes, conform in direction to the directions of these planes.

Application of Methods.

In applying the above principles to the structural study of the crystalline belt in southwestern New England, advantage has been taken of two important considerations.

1. *The areas of most intricate areal development of the formations are key areas for determination of the manner of deformation.*—In geological mapping it is almost an unwritten law that geological sequences must be established in areas where formations appear in their larger masses at the surface, it being generally assumed that structural relationships are in such cases the simpler. Those areas, on the other hand, which exhibit a considerable number of formations brought closely together in small masses at the surface are apt to be looked upon with suspicion as areas of local and so-called "minor" faulting, or as containing intercalated beds of unusual types due to purely local conditions of sedimentation. Whichever of these views be assumed, the areas are likely to receive but

small attention: first, because the problem of their structure is difficult to solve and perhaps is not regarded as affecting the larger questions of the region; and, second, because if once solved the scale of the map would not allow of its representation. Such areas are therefore more frequently represented upon the map in the color of the formation which is believed to compose their greater part.

However unsuited these intricate areas may be supposed to be for establishing the order of succession of geological formations, they are, nevertheless, it is believed, in many cases the keys, and in some cases the only ones, to unlock the secret of the manner of deformation which has affected the region as a whole. Complicated though these problems may be, they often require only patience and industry for their solution, whereas the larger masses by their very simplicity of areal distribution allow of several hypotheses, any one of which would explain them.

Four areas of exceptionally intricate areal relations and widely separated in the region were selected for study. They are the area of sharp ridges near Lee, Massachusetts; Evergreen Hill in Stockbridge, Massachusetts; the Sheffield-Salisbury area; and the Greater New York area. Between the two last mentioned is located the Pomperaug valley area, which, from its detailed mapping, may be counted as a fifth. The Greater New York area has been discussed in papers before the New York Academy of Sciences* and the Geological Society of America.†

After working out so far as possible the local conditions of deformation within the circumscribed areas above mentioned, the larger surrounding areas have been studied not only with respect to the kind of rock and the inclination of its plane of lamination at each locality (as usually done), but the broad distribution of outcroppings, the direction of outcrop margins, the lineaments of the landscape as revealed in topographic relief and drainage lines, and the directions of joints and faults, have all been considered in their relation to the structure disclosed within the smaller areas.

2. *Fault structures are best preserved by the more resistant rock masses.*—Revelations of fault structure through the topographic relief are most likely to be made in areas where the more resistant rock masses are at the surface. The perfection of fault structures preserved in the Newark areas is in no small measure accounted for by the presence there of the dense resistant basalt masses. So resistant a type is not found within

* See review of this paper in Science, xvi, pp. 905-906, 1902.

† Read at Washington December, 1902. See review in Science, xvii, 298 (1903).

the crystalline belt, but some approach to it is afforded by a zone of silicified limestone or dolomite lying between Sheffield, Massachusetts, and Falls Village, Connecticut. This zone of silicification has been supposed to be accounted for by fracture and infiltration along a fault and has already been designated the Housatonic fault.*

Conclusions.

As a result of the studies of these areas it may be stated that, based upon the peculiarities of faults and of fault systems as outlined above, an abundance of evidence has been discovered to show that the area of soutwestern New England has been deformed by a system of joints and faults of post-Newark age superimposed upon older structures which appear to be largely due to folding. The system of faults conforms in direction with the system of joints and is in fact occasioned by a displacement which has occurred along the joint planes. The evidence of this can only be presented with the aid of detailed maps of the several areas accompanied by full descriptions and illustrations. The present paper can therefore be considered only as a preliminary notice of a larger work to appear in a professional paper of the United States Geological Survey. The relative importance of the fold structure and the superimposed fault structure it is difficult to estimate quantitatively. It appears, as expected, that both have played their part, but the result of the investigation has been to show that, so far as the areal distribution of formations and the directions and positions of their mutual boundaries are concerned, the rôle of the system of folds has been altogether subordinate to that of the system of Post-Newark faults.

Madison, Wisconsin.

* Jour. Geol., i, pp. 793–798 (1893).

ART. XLIV.—*A New Machine for Tracing Speech Curves;** by E. W. SCRIPTURE.

A GRANT from the Elizabeth Thompson Science Fund rendered it possible to construct a machine to trace off the speech curves on the celluloid cylinders of the Lioret phonograph, and to thus extend to the study of French the methods of work already applied to English and German.†

The celluloid cylinders are the invention of Dr. H. Lioret of Paris; they are practically indestructible. Those of Model A are 55^{mm} in diameter and 43^{mm} in length. The speech groove consists of depressions just as in the ordinary wax phonograph. They reproduce the voice with great truthfulness. For tracing the speech groove we remove the cylinder from its brass frame and place it on the rotator (fig. 1). This is a steel barrel having a tapered end for the cylinder. It is rotated by a motor. The speed of the motor is twice reduced to $\frac{1}{180}$ by combinations of a worm and a 160-tooth spur gear, and finally to $\frac{1}{8}$ by the pulleys, giving a total reduction to $\frac{1}{288800}$. The speed of the motor is so adjusted that the cylinder turns once in $4\frac{1}{2}$ hours.

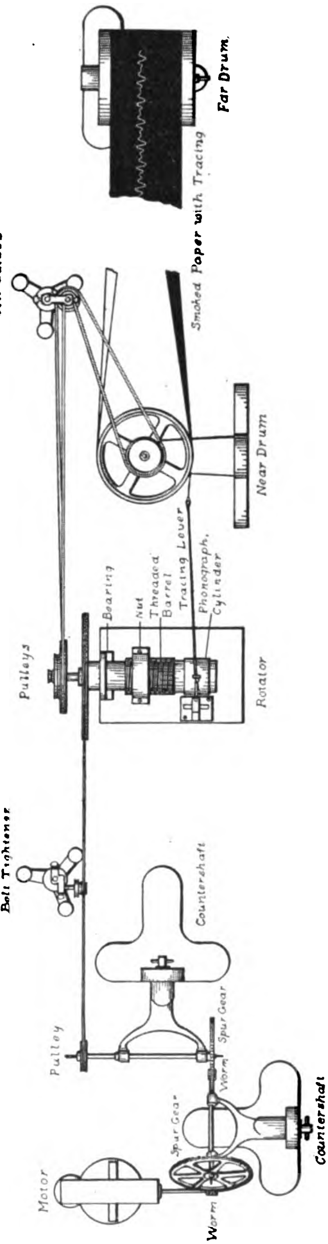


FIG. 1. Tracing Machine for the Lioret Phonograph Records. (Top View; scale, 1 : 12.)

As the barrel turns, it is made to move axially by a thread turning in a brass nut. An additional bearing takes the strain of the pulleys and relieves the nut. The celluloid cylinder thus turns and moves axially in such a way

* Elizabeth Thompson Science Fund.
† Scripture: Experimental Phonetics, Chapter IV.

that the speech groove passes under a sapphire point which follows the rise and fall in the bottom of the groove and moves a light tracing lever. The point of this lever records the movement on a long band of smoked paper passing over two drums. The near drum is run by a belt directly from the rotator. The speech curve appears in great magnification on the band of smoked paper. When the band has gone once around, the record is fixed by brushing the *back* of it with an alcoholic solution of shellac; this fixes the smoke from the back and produces a mat surface.

The tracing lever is the critical part of the apparatus. Fig. 2 shows the end view of the rotator with the phonograph cylinder. The sapphire at the end of a steel point follows the rise and fall of the speech groove. The fulcrum of the lever

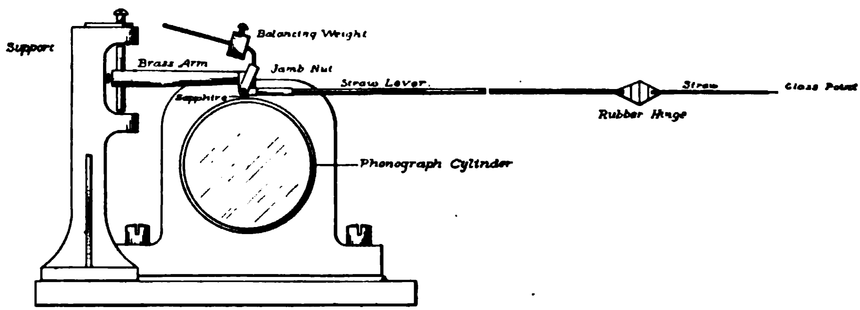


FIG. 2. Tracing Mechanism. (Side view; scale, 1 : 3.)

to which it is attached is just to the left of it. The long arm is made of two selected German straws of unusual lightness and rigidity. This is balanced by a weight. The end of the straw arm carries a somewhat modified Baylis point. This consists of two small bits of cardboard united by a hinge of the finest rubber membrane. One piece is attached to the tracing lever, while the other carries a piece of light French straw with a minute glass ball at the end. This form of recording point gives a minimum of friction.

Since there is no springiness in the rubber hinge the glass point will not remain in contact with the paper. Springiness was attempted by putting a fine hair across the hinge; the result was not satisfactory, as too light pressure would allow the point to leave the drum when the speech curve deviated from the vertical plane, and too heavy pressure diminished the amplitude. By slightly tipping the hinge gravity could be made to keep the point on the paper. Since it is impossible to get the cylinder on the rotator so that the speech grooves lie in absolutely vertical planes, some arrangement must be made

for side motion. This is done by supporting the tracing lever at the end of a brass arm which is pivoted in vertical bearings.

The delicacy of adjustment of the bearings of both the tracing lever and the brass arm must be very great. The methods of testing and adjusting have to be acquired as an art, and a description would be both tedious and useless. The delicacy of the recording point is so great that if one finger is placed on the metal base of the rotator and another on the very stout upright support bolted rigidly to the base, the recording point will indicate the yield of the two pieces of metal.

For tracing paper it has been found best to use unglazed box paper. A careful test showed that with the Baylis point there was no diminution in the amplitude of the waves due to friction on the paper.

To avoid jarring, the whole apparatus is placed on a board which is suspended from the ceiling by cords attached to springs.

A specimen of the tracing of a French vowel is shown in natural size in fig. 3.

FIG. 3. Vowel Curve. (Scale, 1 : 1.)

By applying to M. Henri Lioret, 12 rue Thibaud, Paris, a record of any person will be made to order at the regular price of 2 frs. 50. It would be quite feasible for any one in Paris who is interested in French dialects to bring the proper persons to the above address and have the cylinders made. They could then be traced off by the machine and the results delivered to the person ready to study them. I have had a number of records made by one person, including *Le Roi d' Yvetot*, *Le Corbeau et le Renard*, *Anecdotes linguistiques*, *Lafon et l'Amateur*, *Amusettes phonétiques*, *Sur un Mort*, and portions of *Le Bourgeois Gentilhomme*.

This machine has now traced off a series of words containing typical French sounds. As these results fully occupy the one person for whom they were made, I am ready to trace off any of the cylinders already on hand or any other cylinders for any one who wishes to prepare the results for publication. As no accurate curves of French speech have ever been made, these results would have immediate value.

Yale University, New Haven, Conn.

ART. XLV.—*New Forms of Sperrylite*; by VICTOR GOLDSCHMIDT and WILLIAM NICOL.

THE sperrylite examined by us during the summer of 1902 was obtained at the Vermillion Mine, Algoma District, Province of Ontario. This is the original locality from which was obtained the material examined by Wells and Penfield* and that described by Walker.† By "panning" the loose material at the mouth of the old shaft a heavy residue was obtained. When this residue was examined by a needle and pocket lens the brilliant silver-white crystals of the mineral were readily separated from the magnetite, etc., occurring with them. The crystals are exceedingly small, but on account of their brilliant metallic lustre the measurement of the minute faces was easily possible. The crystals were measured on the two-circle reflecting goniometer, making use of the reduced signal.

Nine crystals were measured, which showed the following forms:

Crystal System Regular. Pentagonal Hemihedrism.

Letter:	c	*a	*g·	e	*h	*b·	∂	*k	*m	*q	*B	p	*u	*ψ	*x
Symb. Gdt.:	0	$+\frac{1}{3}0$	$-\frac{2}{5}0$	$+\frac{1}{2}0$	$+\frac{3}{5}0$	$-\frac{2}{3}0$	-10	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{5}$	1	$1\frac{1}{2}$	$\frac{1}{2}\frac{1}{4}$	$-\frac{2}{3}\frac{1}{3}$
Symb. Miller:	001	103	$\bar{2}05$	102	305	$\bar{2}03$	$\bar{1}01$	114	113	112	335	111	212	214	$\bar{2}13$

Of these forms, those designated with an asterisk are new for sperrylite. In addition to these, two other forms,

$$?\,z = +\,\tfrac{3}{5}\tfrac{1}{5}\,(315); \quad ?\,D = +\,\tfrac{1}{2}\tfrac{1}{3}\,(326),$$

were observed, but not with absolute certainty.

Charles W. Dickson,‡ doing post-graduate work at the School of Mines, Columbia University, New York, has succeeded in separating sperrylite crystals from the unaltered chalcopyrite from the Victoria Mine, in the Sudbury District. He reports by letter, "I found, on examination of two of the best crystals, the trapezohedrons 211 and 411, besides the originally described forms."

The form e occurs on all the crystals measured, having only half the number of faces developed, in accordance with pentagonal hemihedrism. This form has been regarded as *positive*, and the *positive* or *negative* character of the other forms has been determined in accordance with this. This criterion may be accepted as decisive. On account of the minute size of the crystals it was not possible to attempt to decide this point by etch-figures.

* This Journal (3), xxxvii, 67 et seq., 1889. Zeitschr. f. Kryst., xv, 285 u. 290, 1889.

† This Journal (4), i, 110 et seq., 1896. Zeitschr. f. Kryst., xxv, 561, 1895.

‡ This Journal (4), xv, 137, 1903.

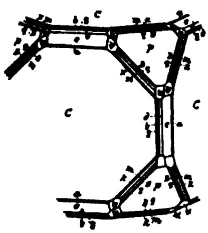
The nine crystals measured showed the following combinations:

Combinations.

Crystal No. 1:	c	.	g'	e	.	b'	.	.	m	q	.	p	u	.	.	.	.	Fig. 2.
Crystal No. 2:	c	.	.	e	.	.	.	.	.	.	.	p	.	.	.	.	.	
Crystal No. 3:	c	.	.	e	.	.	.	.	.	q	B	p	.	.	.	.	.	
Crystal No. 4:	c	.	.	e	.	b'	ð	.	m	q	B	p	u	ψ	x	.	.	Fig. 3.
Crystal No. 5:	c	.	.	e	.	.	ð	k	.	q	.	p	u	ψ	.	(z)	.	Fig. 4.
Crystal No. 6.	c	.	.	e	h	.	.	.	.	.	.	.	.	.	.	.	.	Fig. 5.
Crystal No. 7:	c	.	.	e	.	.	ð	k	m	q	.	p	.	.	.	.	(D)	
Crystal No. 8:	c	a	.	e	.	.	.	.	.	.	.	p	.	.	.	.	.	
Crystal No. 9:	c	.	.	e	.	.	.	.	.	q	.	p	.	.	.	.	.	

From this table of combinations the relative frequency and importance of the individual forms can be observed.

1



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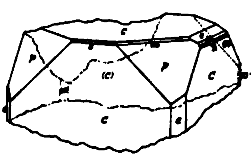

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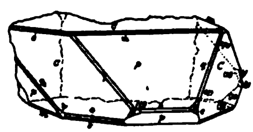


The following arrangement shows the relative importance:

c always present, usually predominating.
p almost always present, usually smaller than **c**, sometimes of equal importance with **c**, now and then predominating.
e always present, but less important by far than **p**.
q ð u m very small, but occurring not seldom.
a g' h b' k B x occurring seldom and unimportant.
z D scarce, faint and uncertain.

Up to the present time, from the measurements of Penfield and Walker, the following forms were known:

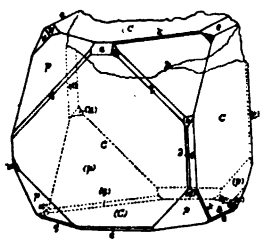
c = 0 (001); ð = 10 (101); e = + $\frac{1}{2}$ 0 (102); p = 1 (111).

These are, in fact, the most important forms. In addition Walker gives the form $\frac{1}{2}\frac{1}{5}$ (5.2.10), determined from measurements of plane angles. This form was not found on any of the nine crystals measured. It lies in the zone + $\frac{1}{2}$ q, between e = $\frac{1}{2}$ 0 and q = $\frac{1}{2}$,—an important zone for this mineral. It may perhaps be identified with the form ψ = $\frac{1}{2}\frac{1}{4}$. In the same zone lies the uncertain form D = $\frac{1}{2}\frac{1}{3}$ and the well defined form u = $\frac{1}{2}$ 1. Figures 2, 3, 4 and 5 show crystals Nos. 1, 4, 5 and 6. Fig. 1 gives an ideal picture of all the forms. Owing to the difficulty of drawing so many narrow faces and reproduc-

ing them by lithographic plate, only part of the crystal is shown. The forms x and h are wanting, as their existence was decided with certainty by measurements made after the drawing was prepared. In figs. 2–5 the attempt has been made to preserve the proportions of the faces as they actually occur in nature.

The measurement, or rather *the discussion of the results of the measurement*, offered several difficulties which can be referred to the small size of the crystals and especially of the subordinate faces. These faces are not only absolutely but also relatively small, that is, when compared as to size, with the principal faces, c and p, they stand far in the background. This may be readily seen from an inspection of the figures. In discussing the measurements in the gnomonic projection,

4



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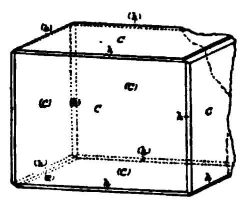

the following unexpected phenomenon was observed. In cases where the principal faces c and p occupied their exact position, showing that the crystal had not been disturbed in its growth, yet the signal reflections from the subordinate faces were displaced in many ways, and this, too, when these faces were well defined as to lustre and perimeter. The minuteness of the subordinate faces is exceptional. It is interesting to note what minute faces can be measured by the excellent instruments of the present day. The following measurements were obtained under the microscope:

Crystal No. 4, Fig. 3.

The large upper c face,	longest diameter = 0·8 ^{mm}
The large front p face,	" " = 0·6
The upper e face, to the right from p,	" " = 0·06
The lower ψ face, to the right from p,	" " = 0·03
The lower x face, to the left from p,	" " = 0·03
The lower *b* face,	length = 0·3^{mm} ; width = 0·015

The displacements and consequent variations in the case of such small faces may have two causes:

1. Optical displacement and diffusion of the signal reflection owing to bending of the light. The smaller the face the stronger is this effect and the less the certainty in determining the position of the face.

2. Curvature of faces near the outlines. This is a consideration of importance in connection with the origin of the crystal and demands special study. Sperrylite itself may perhaps furnish suitable material for this on account of its perfect metallic lustre, which makes it possible to secure good signal reflections from even minute faces: on account of the simplicity of the crystal system and the certainty of the elements and calculated angles: on account of the perfect formation of the principal faces, the great variety of kinds of faces and the large number of individual faces, which are incident to the regular system. It may be said: *the degree of perfection of a face is a function of its absolute and relative size.* Very large faces are usually imperfect since their parts and the parts of the layers underneath have a development history exposed to different influences. The faces of smaller crystals are, as a rule, better formed than those of larger crystals. Below a certain size the faces again become more imperfect. This may be assigned to two causes:

1. The relatively small faces are those derived from higher complication. They are weak and more easily displaced. They are mobile, like the leaves and branches in the wind, while the trunk is unmoved.

2. In the case of small faces the marginal parts are relatively large. The marginal parts, however (on edges and corners), are the places at which the particles are bounded only on one side by securely situated particles which are, as well, oriented themselves and have an orienting influence on their neighbors. This is the place of the manifold formation of varying resultants by complication.* The midfield of not too great a face is therefore usually the smoothest. Convexity readily occurs at the perimeter and corners. Small faces lying close together and very little inclined towards one another, frequently shade into each other by rounding. It may happen that *only* the border part is present, no smooth middle part has been formed. If, now, the border part is large relatively, it furnishes much light for the signal reflection. In this way the signal reflection from the inner portion of the face, when this is small and of low brilliancy, may become darkened and eclipsed by that of the border parts. If the faces are too small it is not possible to shut off the border portions by means of the shutter at the eye-piece of the telescope. It is not advisable at this place to go more deeply into these interesting points. They should form the ground of a special investigation.

The discussion of the position of the faces and the symbols of the subordinate ones must be undertaken with caution on the above mentioned grounds. Considerable experience is

* Compare Zeitschr. f. Kryst., xxix, 47, 1897.

necessary in order to be able to separate here the certain from the uncertain. One must also, by measuring numerous crystals, accustom one's self to the peculiarities of the kind of crystal at hand. On the one hand, there is the temptation to symbolize the positions of the diffused signal reflections. This may lead to great confusion. On the other hand, there is the danger of demanding too great precision, and therefore of finding here only the principal forms c, p, e. It was attempted by careful discussion of the measurements and their picture in the gnomonic projection, to obtain as many certain and typical forms as possible. The forms here given as certain may be accepted. Those indicated by (?) viz. z and D, possess a high degree of probability. Under these circumstances a greater variation than usual must be allowed between the positions of the faces as determined by measurement and by calculation.

The new forms are characterized as follows:

a $= + \frac{1}{3}$ **0 (108)** observed on crystal No. 8 with one face,

measured: $\phi\rho = 269° \ 14; \ 71° \ 35$
calculated: $\phi\rho = 270° \ 00; \ 71° \ 34$

The form is a faint or weak one, but certain.

g· $= - \frac{2}{5}$ **0 ($\bar{2}$05)** observed on crystal No. 1 with one small face. On account of the minute size of the face the signal reflection was somewhat extended in the zone c ƃ e; however, it was possible to fix the position. This gave:

Distance from pole, ρ in zone c ƃ e $= 21° \ 36$
calculated, $= 21° \ 48$

b· $= - \frac{2}{3}$ **0 ($\bar{2}$03)** observed on crystal No. 1 in the same zonal part as g·. The signal reflection of the exceedingly small face gave in the zone c ƃ e the distance from pole 35° 22 (calculated = 33° 41). This would not suffice to establish the form. However the form occurs with a better face on the same crystal. This gives a good signal reflection showing the position:

measured: $\phi\rho = 89° \ 27; \ 56° \ 08$
calculated: $\phi\rho = 90° \ 00; \ 56° \ 18$

b· occurs also on crystal No. 4, with one face having the position:

measured: $\phi\rho = 1° \ 43; \ 34° \ 31$
calculated: $\phi\rho = 0° \ 00; \ 33° \ 41$

The form may be considered as established. The simultaneous occurrence of g· and b· in the same zonal part corroborates the symbol from the fact that the law of the number series is

complied with; that is, the numbers form a legitimate series. We have the following discussion of the numbers:*

Letters:		c	g·	b·	δ	e
Symbol pq		0	$\frac{2}{5}0$	$\frac{2}{3}0$	10	20
p	=	0	$\frac{2}{5}$	$\frac{2}{3}$	1	2
$\frac{p}{2}$	=	0	$\frac{1}{5}$	$\frac{1}{3}$	$\frac{1}{2}$	1
$\frac{v\dagger}{1-v}$	=	0	$\frac{1}{4}$	$\frac{1}{2}$	1	∞
2v	=	0	$\frac{1}{2}$	1	2	∞ = normal series N2.

h = + $\frac{3}{5}$ **0 (305)** observed on the peculiar crystal No. 6 (fig. 5), along with the form c = 0. The faces are very narrow and in consequence of this the signal reflections are somewhat extended in the zone; still the form may be considered as established since it occurs on all the edges, and the middle position corresponds to that obtained by calculation. Confusion of this form with the neighboring one e = + $\frac{1}{2}$ 0 is not possible and, moreover, e occurs beside h on two edges. For determining the symbol the angle formed with the adjoining cubic face suffices. This gave for the nine faces capable of being measured the following values:

h:c = 30° 33; 30° 35; 30° 28; 31° 02; 31° 37; 31° 39; 31° 58; 30° 29; 30° 53

Average, measured = 30° 53
calculated = 30° 58

This crystal is peculiar in that the form p, the octahedron, is entirely wanting and the form e as compared with h is unimportant.

k = $\frac{1}{4}$ **(114)** observed on crystal No. 5 with two small faces, the better of which gave the position:

measured: $\phi\rho$ = 13° 46; 76° 07
calculated: $\phi\rho$ = 14° 02; 76° 22

This form occurs again on crystal No. 7 with one face, which is uncertain, however.

m = $\frac{1}{3}$ **(113)** observed on crystal No. 1 with two small faces in the zone c p, the better of which gave the position c m =

* Concerning such a discussion of numbers compare Zeitschr. f. Kryst., xxviii, 24, 1897.

† v indicates always the member of the previous series which is to be transposed to the corresponding one of the following series.

25° 05, calculated c m = 25° 14. The same form was observed on crystal No. 4, with three faces, with the positions:

Measured.		Calculated.	
ϕ	ρ	ϕ	ρ
133° 18	24° 57	135° 00	25° 14
162° 33	73° 12	161° 34	72° 27
$\bar{4}$5° 05	25° 26	$\bar{4}$5° 00	25° 14

This form may be considered as established.

q = ½ **(112)**, after c p e the most important form of *sperrylite*. It was observed on crystal No. 4 with four faces. The best of these gave the position:

measured: $\phi\rho$ = 44° 36 ; 35° 12
calculated: $\phi\rho$ = 45° 00 ; 35° 16

also on crystal No. 1 this form was observed with two uncertain faces, and on crystal No. 5 with five faint faces, the two best of which gave the position:

measured: $\phi\rho$ = 135° 32; 34° 11 | measured: $\phi\rho$ = $\bar{4}$4° 30; 34° 08
calculated: $\phi\rho$ = 135° 00; 35° 16 | calculated: $\phi\rho$ = $\bar{4}$5° 00; 35° 16

On crystal No. 7 this form appeared with four faint faces and on crystal No. 3 with three faces, the best of which gave the position:

measured: $\phi\rho$ = $\bar{4}$4° 36 ; 35° 12
calculated: $\phi\rho$ = $\bar{4}$5° 00 ; 35° 16

It appeared again on crystal No. 9 with four small faces with extended signal reflection.

B = ⅗ **(335)** observed on several crystals, established, however, only by two faces, one on crystal No. 3 and another small, though good face, on crystal No. 4.

Crystal No.	Measured.		Calculated.	
	ϕ	ρ	ϕ	ρ
3	$\bar{1}$33° 30	39° 56	$\bar{1}$35° 00	40° 19
4	135° 07	39° 42	135° 00	40° 19

It is a poorly developed form.

u = **1½ (212)** observed on crystal No. 1 with one face, on crystal No. 4 with two faces, and on crystal No. 5 with seven faces. Position:

Crystal No.	Measured.		Calculated.	
	ϕ	ρ	ϕ	ρ
1	46° 46	67° 50	45° 00	70° 31
4	43° 30	68° 39	$\bar{4}$5° 00	"
	44° 37	70° 03	45° 00	"
5	135° 32	69° 58	135° 00	"
	$\bar{1}$35° 35	67° 57	$\bar{1}$35° 00	"
	$\bar{2}$7° 17	48° 06	$\bar{2}$6° 34	48° 11
	28° 32	48° 31	26° 34	"
	46° 29	70° 23	45° 00	70° 31

The faces are very small, but their frequent occurrence gives them some importance.

$\psi = + \frac{1}{2}\frac{1}{4}$ **(214)**, a form important for *pyrite*, occurs on crystal No. 4 with three faces, and on crystal No. 5 with two faces. The faces are very small but possess brilliant lustre.

Position:

Crystal No.	Measured.		Calculated.	
	ϕ	ρ	ϕ	ρ
4	$\bar{1}$17° 02	79° 45	$\bar{1}$16° 34	77° 23
	$\bar{6}$5° 19	78° 16	63° 26	"
	167° 16	66° 10	165° 58	64° 07
5	75° 18	65° 05	75° 58	"
	152° 52	29° 00	153° 26	29° 12

x $= - \frac{2}{3}\frac{1}{3}$ **($\bar{2}$13)** observed on crystal No. 4 with one well bordered face giving a good signal reflection. Position:

measured : $\phi\rho = \bar{1}47° \ 05 \ ; \ 74° \ 57$
calculated : $\phi\rho = \bar{1}46° \ 19 \ ; \ 74° \ 30$

The agreement is satisfactory. The form may be considered as established.

? **z** $= + \frac{3}{5}\frac{1}{5}$ **(315)** observed on crystal No. 5 with one triangular face. Position:

measured : $\phi\rho = 48° \ 50 \ ; \ 79° \ 27$
calculated: $\phi\rho = 49° \ 02 \ ; \ 80° \ 16$

Owing to this agreement the form is a probable one, but confirmation is to be desired. Till that is obtained the form is indicated by a (?).

? **D** $= + \frac{1}{2}\frac{1}{3}$ **(326)** observed on crystal No. 7 with one face. Measurement and calculation do not agree very well. The form needs confirmation. Position:

measured : $\phi\rho = 159° \ 10 \ ; \ 64° \ 39$
calculated : $\phi\rho = 161° \ 34 \ ; \ 64° \ 37$

Table of Angles.*

No.	Letter.	Symb.	Miller.	ϕ	ρ	ξ_0	η_0	ξ	η	X (Prisms) (x : y)	y	d = tg ρ
1	c	0	001	—	0°00	0°00	0°00	0°00	0°00	0	0	0
		0∞	010	0°00	90 00	"	90 00	"	90 00	"	∞	∞
		$0\frac{1}{3}$	013	"	18 26	"	18 26	"	18 26	"	0·3333	0·3333
2	a	03	031	"	71 34	"	71 34	"	71 34	"	3·0000	3·0000
		∞3	130	18 26	90 00	90 00	90 00	18 26	"	0·3333	∞	∞
		$0\frac{2}{5}$	025	0 00	21 48	0 00	21 48	0 00	21 48	0	0·4000	0·4000
3	g	$0\frac{5}{2}$	052	"	68 12	"	68 12	"	68 12	"	2·5000	2·5000
		$\infty\frac{5}{2}$	250	21 48	90 00	90 00	90 00	21 48	"	0·4000	∞	∞
		$0\frac{1}{2}$	012	0 00	26 34	0 00	26 34	0 00	26 34	0	0·5000	0·5000
4	e	02	021	"	63 26	"	63 26	"	63 26	"	2·0000	2·0000
		∞2	120	26 34	90 00	90 00	90 00	26 34	"	0·5000	∞	∞
		$0\frac{3}{5}$	035	0 00	30 58	0 00	30 58	0 00	30 58	0	0·6000	0·6000
5	h	$0\frac{5}{3}$	053	"	59 02	"	59 02	"	59 02	"	1·6667	1·6667
		$\infty\frac{5}{3}$	350	30 58	90 00	90 00	90 00	30 58	"	0·6000	∞	∞
		$0\frac{2}{3}$	023	0 00	33 41·	0 00	33 41·	0 00	33 41·	0	0·6667	0·6667
6	b	$0\frac{3}{2}$	032	"	56 18·	"	56 18·	"	56 18·	"	1·5000	1·5000
		$\infty\frac{3}{2}$	230	33 41·	90 00	90 00	90 00	33 41·	"	0·6667	∞	∞
7	d	01	011	0 00	45 00	0 00	45 00	0 00	45 00	0	1·0000	1.0000
		∞	110	45 00	90 00	90 00	90 00	45 00	"	1·0000	∞	∞
8	k	$\frac{1}{4}$	114	"	19 28	14 02	14 02	13 38	13 38	0·2500	0·2500	0·3535
		14	141	14 02	76 22	45 00	75 58	"	70 32	1·0000	4·0000	4·1231
9	m	$\frac{1}{3}$	113	45 00	25 14·	18 26	18 26	17 33	17 33	0·3333	0·3333	0·4714
		13	131	18 26	72 27	45 00	71 34	"	64 45·	1·0000	3·0000	3·1623
10	q	$\frac{1}{2}$	112	45 00	35 16	26 34	26 34	24 05·	24 05·	0·5000	0·5000	0·7071
		12	121	26 34	65 54·	45 00	63 26	"	54 44	1·0000	2·0000	2·2360
11	B	$\frac{3}{5}$	335	45 00	40 19	30 58	30 58	27 13·	27 13·	0·6000	0·6000	0·8485
		$1\frac{5}{3}$	353	30 58	62 46·	45 00	59 02	"	49 41	1·0000	1·6667	1·9437
12	p	1	111	45 00	54 44	45 00	45 00	35 16	35 16	1·0000	1·0000	1·4142
13	u	$\frac{1}{2}1$	122	26 34	48 11·	26 34	"	19 28	41 48·	0·5000	1·0000	1·1180
		2	221	45 00	70 31·	63 26	63 26	41 48·	"	2·0000	2·0000	2·8284
		$\frac{1}{4}\frac{1}{2}$	124	26 34	29 12·	14 02	26 34	12 36·	25 52·	0·2500	0·5000	0·5590
14	ψ	$\frac{1}{2}2$	142	14 02	64 07·	26 34	63 26	"	60 47·	0·5000	2·0000	2·0615
		24	241	26 34	77 23·	63 26	75 58	25 52·	"	2.0000	4·0000	4·4721
		$\frac{1}{3}\frac{1}{2}$	236	33 41·	31 00	18 26	26 34	16 36	25 22·	0·3333	0·5000	0·6009
15	?D	$\frac{2}{3}2$	263	18 26	64 37·	33 41·	63 26	"	59 00	0·6667	2·0000	2·1130
		$\frac{3}{2}3$	362	26 34	73 24	56 18·	71 34	25 22·	"	1·5000	3·0000	3·3541
		$\frac{1}{3}\frac{2}{3}$	123	"	36 42	18 26	33 41·	15 30	32 18·	0·3333	0·6667	0·7453
16	x	$\frac{1}{2}\frac{3}{2}$	132	18 26	57 41·	26 34	56 18·	"	53 18	0·5000	1·5000	1·5811
		23	231	33 41·	74 30	63 26	71 34	32 18·	"	2·0000	3·0000	3·6055
		$\frac{1}{5}\frac{3}{5}$	135	18 26	32 18·	11 18·	30 58	9 44	30 28	0·2000	0·6000	0·6325
17	?z	$\frac{1}{3}\frac{5}{3}$	153	11 18·	59 32	18 26	59 02	"	57 41·	0·3333	1·6667	1·6996
		35	351	30 58	80 16	71 34	78 41·	30 28	"	3·0000	5·0000	5·8310

* In the table of angles the ± forms are not separated.

Heidelberg, Germany, and
School of Mining, Kingston, Canada.

ART. XLVI.—*The Niagara Domes of Northern Indiana;* by EDWARD M. KINDLE.

THE earlier workers on the geology of Indiana generally believed the geological structure of the State to be much simpler than recent investigations have shown it to be. Their firmly-rooted belief in the uniformity of the geological structure of Indiana prevented many of them from even entertaining any explanation of the Niagara dips which would include deformation. Prof. John Collett, for many years State Geologist, says in describing Niagara beds which show dips: . . . "the uniform undisturbed condition of the strata of this and adjoining states will not allow the presumption of upheaval and such dislocation of strata as would account for these phenomena."* Starting with the assumption of the "undisturbed condition" of the strata, it is not surprising that Collett was compelled to confess, in describing a locality exhibiting tilted beds, that, "This quarry is a mystery."†

It will be the purpose of the following pages to show that we have in the Niagara beds of northern Indiana a notable exception to the nearly horizontal and undisturbed condition which generally characterizes most of the other formations in Indiana. A number of theories concerning the structure of the Niagara area and the dips have been advanced, and the more important ones will be briefly reviewed.

Owen.—Richard Owen first directed attention to the tilted Niagara rocks of northern Indiana. Forty years ago Owen wrote that he had found near Delphi, "A local dip to the southeast amounting to 40°."‡ He mentioned also the sharp dips at Wabash and Huntington.

Cox.—Ten years later E. T. Cox, then State Geologist, gave a brief description of these localities, but ascribed the inclined beds to false bedding.§

Oblique or false bedding on a large scale is an unusual phenomenon in limestones. The seas in which they are deposited are seldom sufficiently shallow to permit the action of currents strong enough to produce oblique bedding. As a possible explanation of the dips, however, the hypothesis of oblique bedding proposed by Cox deserves an examination. The history of the discussions concerning the LeClaire limestone of Iowa illustrates the difficulty sometimes met with in discovering positive evidence as to the character of bedding.

* 12th Ann. Rep. Ind. Geol. Surv., p. 59. † L. c.
‡ Ind. Geol. Surv., 1859–60, p. 98, 1862.
§ Ind. Geol. Surv., 1872, p. 307.

Even where true bedding seems obvious it is not always easy to discover in the strata intrinsic evidence which will entirely eliminate the possibility of false bedding. At a number of localities highly inclined beds richly fossiliferous have been observed in contact with barren or nearly barren beds where the evidence of tilting seemed so clear as to require no special comment but for the fact that the opposite opinion has been held regarding them. The final test of the false bedding

1

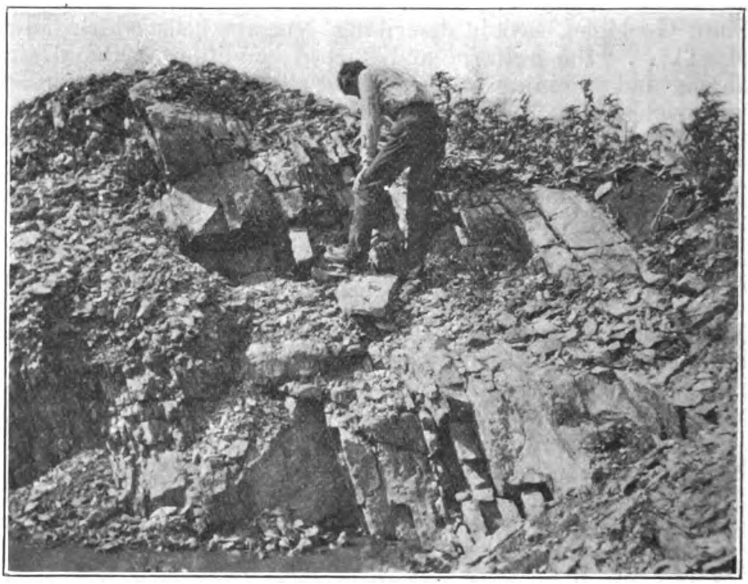

FIG. 1.—Tilted beds near Kentland.

hypothesis comes in applying it to particular cases. Does it afford a satisfactory explanation of such examples as the following? Near Delphi a bed fifteen feet or more in thickness occurs, composed almost entirely of the shells of *Conchidium laqueatum* one to three inches in length, which is inclined at an angle of 20°. While it is perhaps not impossible that such a bed should occur in false bedded strata, it appears to the writer highly improbable. In the case, however, of strata having a dip of 70° or more, as shown in fig. 1, oblique bedding cannot be considered even as a possible explanation. The materials composing the beds, if piled in layers inclined at such a high angle, could not retain their position. Deformation alone offers a satisfactory explanation of such dips.

Gorby.—In 1886 S. S. Gorby* described a considerable number of outcrops showing tilted strata, and announced that they indicated a great anticlinal, "extending entirely across the State," which he called the "Wabash arch." Many of the dips recorded by the author of this hypothetical arch afford evidence against it. About half of them are east or west dips, while the supposed arch has a southeast and northwest axis, which calls for northeasterly and southwesterly dips, and fails to explain the others. Phinney in discussing the "Wabash arch" points out that the gas well records furnish evidence against it.

Phinney.—The tilted strata are, according to Phinney, due to irregularity of deposition rather than to deformation, and he states that they are "to be attributed to the building up of coral reefs and rocky prominences over portions corresponding to the domes and offshoots of the Cincinnati arch or to irregularities in the sea-bottom."† A serious objection to the coral reef theory is the absence of the reefs. Corals are not at all abundant in the Niagara of northern Indiana. They have not been observed anywhere in sufficient abundance to form reefs. While inequalities in the sea-bottom may be responsible for some of the smaller undulations in the strata, neither they nor "offshoots of the Cincinnati arch" appear to offer a satisfactory explanation of dips of 45° to 75° in the Niagara rocks, which the accompanying photographs show.

Thompson.—Maurice Thompson considered the dips to be the result of the disturbance of beds originally horizontal. He states: "The structure of the Niagara limestone does not in the least indicate false bedding."‡ Thompson accepted Gorby's hypothetical "Wabash arch," but evidently had a pretty clear understanding of the local dome-like structures in the Niagara. A summary of his views is best stated in his own words: "The arch formed by this upheaval consists of a vast series of low bubbles or cones that make the surface of the Niagara limestone somewhat like that of a sea in a brisk breeze."§

Elrod and Benedict.—In the same volume with Thompson's paper appeared a paper by M. N. Elrod and A. C. Benedict on a portion of the northern Indiana Niagara area. These authors conclude that the Niagara "cones" which they describe are the result of a variety of cleavage which simulates stratification, and cuts across the original bedding planes.

* 15th Ann. Rep. State Geol. of Ind., 1886, p. 241.
† 11th Ann. Rep. U. S. Geol. Surv., p. 653.
‡ 17th Ann. Rep. Ind. Geol. Surv., 1891, p. 183.
§ Ibid., p. 185.

A second paper by the same authors appeared in 1894 in which they deny that there has been any tilting of the Niagara beds of the Wabash Valley.* Cleavage or a "modified form of joint structure" is the explanation offered of the dips. This hypothesis would deserve careful consideration but for the testimony of the fossils. The occurrence of richly fossiliferous bands running parallel with the so-called cleavage planes affords conclusive evidence that they are true bedding planes.

Kindle.—During the summer of '99 the writer visited a number of outcrops in northern Indiana and became convinced that the dips of the Niagara outcrops in northern Indiana were not apparent but real dips. Two of the outcrops showing tilted strata were described in a recent paper.†

Distribution and Composition of Beds.—The area in which tilted rocks occur extends from the Illinois line in Newton County eastward nearly to the Ohio line, embracing the upper Wabash Valley. Highly tilted beds occur in Hamilton County, seventy miles south of the Wabash. It is probable that the Niagara rocks in the intervening territory have heavy dips at many localities, but the thickness of the drift over this area makes it impossible to ascertain whether or not this is true.

The Niagara rocks of this region consist principally of magnesian limestones varying in texture from the very hard close-grained gray limestone breaking with conchoidal fracture to a soft, easily crumbling buff limestone. Beds of buffish or drab calcareous shale are sometimes associated with the limestone. Local lenses of sandstone have been observed in the Niagara limestone at some localities. One of these near Kenneth has a thickness of five and one-half feet, and is composed of pure white quartz sand containing only a trace of calcium carbonate and iron. The Niagara outcrops show only a small portion of the total thickness of the formation, none of the sections extending down to the Lower Silurian. The information which we have concerning its thickness is derived from well records. From these it appears that the Niagara has a thickness of from 250′ to 500′. It does not appear practicable at present to divide these beds into two or more divisions, although detailed study of the paleontological material which has been collected may indicate the desirability of such a division.

There are local facies with characters peculiar to themselves, but not persistent for any considerable distance. A good example of this is seen at the quarries at Decatur. The lime-

* 19th Ann. Rep. State Geol. of Ind., p. 22.
† This Journal (4), xiv, pp. 221–224.

stone in the quarry at the north side of the town is a soft saccharoidal, nearly pure white stone, while at the Bowers quarry, one-third of a mile to the northwest, the rock at apparently the same horizon is a very hard gray dolomitic limestone.

The paleontological data for the correlation of the beds under discussion with the Niagara of New York was presented in a previous paper* by the writer. The beds appearing at the localities then described are identical in faunal and physical characters with those occurring elsewhere in the northern Indiana area. It appears therefore desirable to continue to use the term Niagara, which has long been applied to the dolomites of northern Indiana.

Structure.—The general structure of the Niagara of northern Indiana is that of a broad arch with gently sloping sides trending northwest and southeast. It represents a northwestern extension of the Cincinnati geanticline. Its axis, approximately located, enters the State near Richmond, and passes northwesterly in the vicinity of Muncie, Marion, and Peru, and continues north of the Wabash through Cass, White, Jasper, and Newton counties into Illinois. On the two sides of this line of maximum elevation of the Niagara, the Devonian and Carboniferous rocks dip in opposite directions; in Michigan and Ohio, toward the north and northeast; in Indiana, toward the southwest or south. The following table shows the elevation of the top of the Niagara A. T. along a line approximately at right angles to this axis, extending from Crawfordsville to Auburn, Indiana, a distance of 140 miles.

Crawfordsville	81 A. T.
Frankfort	463
Kokomo	778
Wabash	652
Columbia City	599
Auburn	50

The arch described above is not the "Wabash arch" of Gorby, which apparently was supposed by its author to follow the Wabash Valley in eastern Indiana. The tilted beds which were cited as the evidence of the "Wabash arch" will be shown in another part of this paper to be independent of the above described arch in origin.

The figures given above are based upon gas well records published by the Indiana Geological Survey,† in the northern Indiana area.

* This Journal (4), xiv, pp. 221–234.
†16th Ann. Rep. Ind. Geol. Surv., pp. 217-218.

Dips.—A large percentage of the outcrops throughout the Niagara area are characterized by dips of from 5° to 80°. In a few instances the dips represent cleavage planes. In one case (at the Means Quarry, Newton County) both cleavage and bedding planes are well defined and nearly at right angles to each other, both being inclined at a high angle to the horizontal. A few localities have also been noted where the dip is the result of irregular or false bedding. But the great majority of the dips can be referred to neither of these causes. They are clearly the result of the deformation of strata which were originally horizontal.

A brief study of the tilted beds will suffice to show that they are not referable to ordinary anticlines. A description of the beds near Kentland will illustrate this. At the Means Quarry (N.E. of N.W. of sec. 25) the rock is a hard gray limestone very fine-grained, in strata 3″ to 25″ in thickness, dipping N. 60° to 65°, with strike of N. 82 E. At the McKee quarry, less than half a mile to the east, the strata dip 70° to 75° toward the east with a strike of N. 12° W., or nearly at right angles to the strike at the Means quarry.

Numerous exposures of the Niagara limestone occur near Delphi which show dips of from 10° to 45°. The dips here, like those at Kentland, do not conform to an anticlinal structure but appear to be quaquaversal.

Domes.—At Wabash a fine exposure of the Niagara occurs near the railroad station which affords a key to the puzzling dips at Kentland and other points where only small exposures can be seen. A railroad cut has exposed a cross section through the center of a small dome in the Niagara limestone and shale. In passing through the cut the beds are seen dipping in all directions from the center. On the northeast, east, and south of the dome the Wabash River has denuded the dome of superficial deposits and the beds are seen dipping sharply in these several directions, as shown in the accompanying photographs. At the south end of the cut the strata dip 25° to 30° S. 40 W. Toward the north end of the cut they are seen dipping to the northwest and north. On the east side the dips are east and southeast. The width of the dome from north to south exposed in the cut is about 840′. A portion of the south side of the dome has been removed by erosion. It is estimated that the total north and south diameter has been about 1150′. The excavation for the railroad gives a continuous exposure from the center of the dome of the Niagara shale and limestone for half a mile. The dips of the beds going north from the center of the dome are observed to drop down gradually from a maximum of 30° to perfectly horizontal beds. No dips or other disturbances are noticeable in

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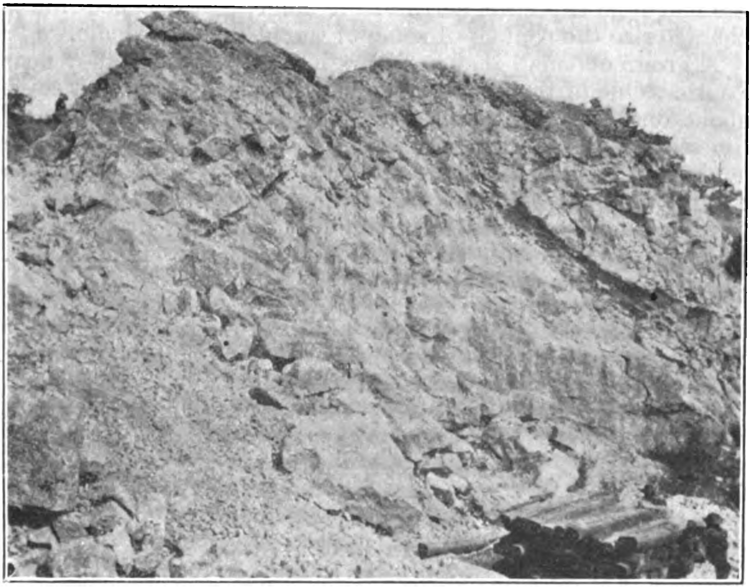

Fig. 2.—N. E. part of Wabash dome.

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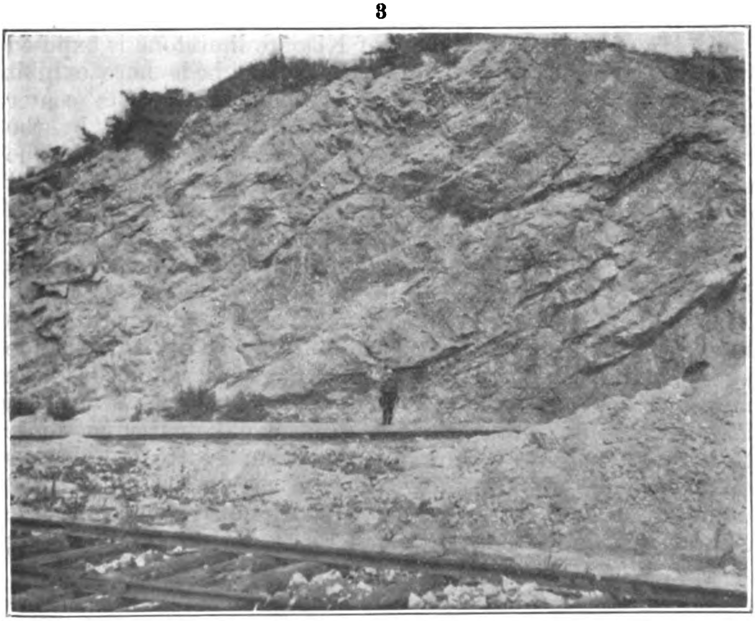


Fig. 3.—S. W. part of Wabash dome.

the half mile exposure, north of the dome. "Slickened-sides" characterize the contact of some of the beds in the dome.

A group of small domes occurs in the Wabash Valley near Lagro. One of these, known as the Hanging Rock, is situated about one mile southeast of Lagro. It consists of a mass of limestone and shale which rises abruptly from the bank of the Wabash River to a height of about eighty feet. The beds exhibit quaquaversal dips and represent a part of a dome, the north and east sides of which have been cut away by the river. The upper beds dip to the south and west at an angle of 25°. The lower strata are less inclined.

4

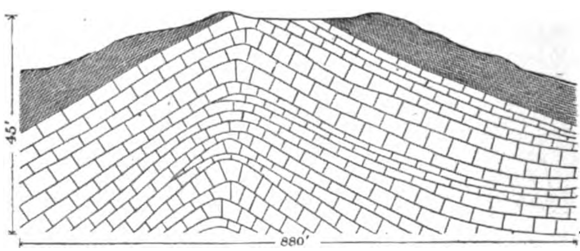


Fig. 4.—Cross section of Wabash dome.

At Huntington, a large area of Niagara limestone is exposed at the quarry one mile east of town. The beds here exhibit quaquaversal dips and indicate a dome having its center within and near the east side of the area exposed by the quarry. The highest dips noted here are 35° or 40°. The exposures are not sufficiently extended to determine the exact diameter of the dome, but from the horizontal strata exposed in nearby outcrops it is probable that it does not exceed 2000′. At the old quarry, a quarter of a mile northeast, the strata are horizontal.

The quaquaversal dips show a general tendency to drop rapidly from a high inclination to nothing. This is noticeable at the quarry half a mile west of Huntington. The beds in the new quarries on the north side of the railroad show a dip of 25° to the south, while the strata in the old quarry not more than 100 yards away show dips of from 1½° to 0. It was doubtless the proximity of outcrops showing highly tilted strata to those of horizontal beds which led Owen* into the error of reporting tilted Devonian rocks at Huntington resting

*Ind. Geol. Surv., 1859-60, p. 66.

unconformably on horizontal Niagara beds. Neither Devonian beds nor unconformity exist in the vicinity of Huntington.

It has been shown that the dips observed in at least three localities are quaquaversal and the expression of dome structure. Nowhere in the area does the strike and dip of the beds conform to an anticlinal or synclinal structure. The dips seem everywhere to be quaquaversal and it is believed that all of the tilted Niagara beds of northern Indiana represent small domes similar to those at Huntington.

Origin and Age.—There is at present no positive evidence as to the nature of the forces which produced the domes. It seems probable, however, that they may be analogous in origin to the "mud lumps" at the mouth of the Mississippi. From a recently published description of the "mud lumps" they appear to have a similar structure to the Niagara domes. Harris has studied these interesting masses of recently elevated sea-bottom and states, "That they rise up in domes or anticlinals and preserve their regular bedding is proven by their present structure." *

Whatever the causes may have been which produced the domes, there is clear evidence that they were developed about the close of the Niagara period. Many of them were elevated above the Palaezoic sea, while others probably did not reach its surface. Some of the domes remained above sea-level during a considerable portion of the Devonian age, and there is some evidence that others continued as islands to the end of Devonian time. The evidence of the exposures indicate that the gradual deepening of the Devonian sea which initiated the "Black shale" sedimentation submerged some of the Niagara domes which had remained above sea-level throughout the Corniferous and Hamilton epochs. These conclusions are based upon the relations which have been observed to exist between the Devonian and Niagara beds at Delphi, Georgetown, Kentland, and other localities. At Georgetown, the horizontal Corniferous limestone beds rest on Niagara beds showing a small dip, but there is no evidence of land surface conditions having existed previous to the Corniferous sedimentation at that locality.

Near Delphi, at one locality, horizontal beds of Hamilton age lie unconformably above the Niagara limestone, which shows a dip of 45°; a bed of ferruginous clay and iron ore separate the two. The New Albany shale is seen resting on the Niagara at another locality near the one last mentioned, the ferruginous clay separating these two as in the first instance.

* Geol. Surv. of La., 1902, p. 39.

The highly tilted beds near Kentland occur on high ground in the open prairie remote from any stream. Rocks of later age have been encountered at much lower levels in all directions from this point within two or three miles, and it appears probable that the Kentland dome remained above sea-level until the end of the Devonian or later.

The occurrence of outliers of Mansfield sandstone (Pottsville conglomerate) in the center of the Niagara area of northwestern Indiana near Remington and Jasper indicate that a subsidence occurred after the formation of the Niagara domes in northwestern Indiana which submerged all or nearly all of the Niagara area of that region beneath the Carboniferous sea. The development of the present Niagara arch in northwestern Indiana was therefore of much later date and independent of the formation of the Niagara domes. While the domes date back to the end of the Niagara, the Niagara arch is of Carboniferous or post-Carboniferous age.

The Niagara-Devonian unconformity which has been described, though much more pronounced, may be correlated with that which has been recognized in Shelby County,* Indiana, and with the slight unconformity between the Devonian and Upper Silurian which has been recorded by Newberry,† on the east side of the Cincinnati geanticline. The evidence at hand points to a general elevation of the sea-bottom at the close of the Niagara in the area around the northern end of the Cincinnati geanticline. The resulting shallow sea was doubtless an important factor in the sudden disappearance of the Niagara fauna and the substitution of the coralline fauna of the Corniferous.

U. S. Geological Survey, New Haven, Ct.

* 25th Ann. Rep. Ind. Geol. Surv.
† Geol. Surv. of Ohio, vol. i, p. 106.

ART. XLVII.—*A New (?) Meteoric Iron from Augusta Co., Virginia;* by H. D. CAMPBELL and JAS. LEWIS HOWE.

IN the list of accessions to the mineral collection of Washington and Lee University during the session 1870–71 occurs the following note: "From Wm. N. Wilson, Esq., Augusta County, Va., a fine specimen of meteoric iron." There is no doubt but that the above entry refers to the meteorite now under consideration, inasmuch as it is the only one in the University collection which has no label, and there is no meteorite with the foregoing label. Since 1880 the history of this meteorite is definitely known. From 1886 to 1894 the meteorite was in charge of Professor W. G. Brown. A fragment was cut from one end by him for analysis, the surface etched and photographed but Professor Brown's analysis has not been published,

The question has naturally arisen as to whether this meteorite is from the same fall as the so-called Staunton meteorite which has been several times analyzed and in which Sir William Ramsay found the presence of helium. The meteorite was sent to Professor Henry A. Ward to be again cut and an analysis of it was made for him by Mr. J. E. Whitfield. A fragment was also sent to Dr. Ramsay and examined by him for gases.

The analysis by Whitfield is given together with the other analyses of the Augusta meteorite for comparison, and also the result of the examination by Dr. Ramsay.

	1	2	3	4	5	6	6*a*	7	7*a*
Iron	88·706	88·365	89·007	91·439	90·293	92·49	93·27	89·850	91·376
Nickel	10·163	10·242	9·964	7·559	8·848	6·38	6·04	7·560	7·689
Cobalt	·396	·428	·387	·608	·486	·63	·64	·600	·610
Copper	·003	·004	·003	·021	·016	·0258	...	·065	·066
Tin	·002	·002	·003	trace	·005	...	...	...	...
Phosphorus	·341	·262	·375	·068	·243	·24	...	·158	·161
Sulphur	·019	·008	·026	·018	·012	...	...	·006	·006
Chlorine	·003	·002	·004	trace	trace	...	...	...	...
Carbon	·172	·185	·122	·142	·177	·05	·05	·046	·047
Silicon	·067	·061	·056	·108	·092	...	...	·045	·045
Oxide	...	...	...	...	...	...	...	1·560	...

1. J. W. Mallet, this Journal (3), ii, 10. Mass weighing 56 pounds. 1871.
2. J. W. Mallet, ibid. Mass weighing 36 pounds. 1871.
3. " ibid. Mass weighing 3·5 pounds. 1871.
4. " this Journal (3), xv, 338, 1878.
5. Kunz, this Journal (3), xxxiii, 58, 1887.
6. Cohen, Ann. Hof. Mus., vii, 156, 1892.
6*a*. " ibid. Calculated from 6, less 1·56% schreibersite.
7. Whitfield. Calculated from 7*a*, less oxidized portion. 1901.
7*a*. "

Regarding the gases in the meteorite we are permitted to quote the following from Dr. Ramsay:

"The gases were extracted by heating *in vacuo*. This gas is very curious. There were only 3·52^{cc}, none of it dissolved in KOH, Aq. On mixing with oxygen and sparking, there was contraction, and afterwards a large absorption of CO_2 with potash. The residue was very minute, so small indeed that on letting it into a small exhausted tube it was at phosphorescent stage. But with a jar and spark-gap it was possible to see the argon blues, and without the jar the argon reds were just visible. I think I saw the helium yellow, but it was very feeble. The complete analysis is as follows:

Volume of gas from 6·54 grams of the meteorite, 3·52^{cc}

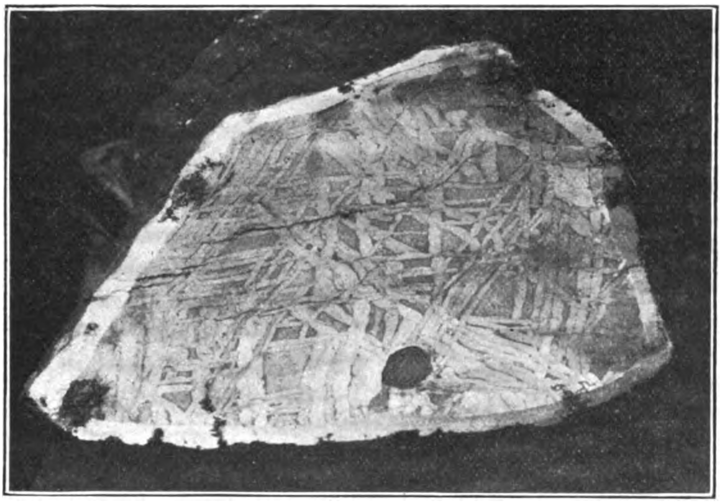
KOH. No contraction.			
Oxygen added	9·18		
	12·70		
After sparking	12·00		
Contraction for H_2O	0·7	×2/3	0·46 H_2
Absorption with KOH	8·83		
CO_2 formed	3·17		3·17 CH_4
Add	0·46		
	3·63		
Argon, etc., say	0·02		0·02 A, etc.
	3·65		3·65 "

Conceivably there may have been a trace of ethane, or of some hydrocarbon richer in carbon, in which case the CO_2 would not have been equal to the CH_4, but greater in volume. This might account for the small discrepancy between the amount taken, 3·52^{cc}, and the total, 3·65."

The question as to whether this meteorite is a portion of the "Staunton" fall is not settled by the analysis. It differs somewhat from the specimens analyzed by Mallet in 1871, but on the other hand it resembles in most particulars that analyzed by Mallet in 1878. It should be noted that Brezina considers that this latter specimen is not from the same fall as those earlier analyzed. The analysis of the gases would seem to point toward the present meteorite being identical with the "Staunton," though it does not decide the question. It is peculiar in containing chiefly methane, but like the "Staunton" contains argon. "Staunton" is the only meteorite reported in literature, so far as we have been able to find, as containing

helium, and in this there was but a trace. In the case of the present meteorite the presence of helium seems probable but not certain.

As regards the etched surfaces, they do not resemble those of the "Staunton." Mr. H. L. Preston has called our attention to the complete absence of the club-shaped "kamacite" blades, so prominent in the "Staunton." These are also lacking in one other mass of the "Staunton," and it was chiefly from this consideration that Brezina held that one to be a distinct fall.



Mr. Wirt Tassin of the United States National Museum has had the kindness to compare the photographs of the etched surfaces with the section of the "Staunton" iron described by Mallet in 1871, and writes as follows: "It shows quite a difference in structure. The 'taenite' plates in the museum specimen are smaller, averaging only half the size of those in the photograph. The specimen also shows numerous fine lines of 'schreibersite,' often regularly arranged—especially in the 'plessite,' and are occasionally so abundant as to give to it (the 'plessite') a stippled appearance. These are lacking in the photograph, although this may be due to differences in illumination. Finally, as you have already remarked, there is the complete absence of the bulb- or club-like 'kamacite' blades."

We propose to call this meteorite "Staunton, No. 7." The original weight of the meteorite was somewhat more than seven kilos; its weight prior to the recent cutting was 7·15 kilos; its present weight is 6·04 kilos.

Washington and Lee University, Lexington, Va.

ART. XLVIII.—*The Diffusion of Vapor into Nucleated Air;**
by C. BARUS.

1. THE apparatus with which experiments of the present kind are made is conveniently described by aid of the accompanying diagram. The appurtenances necessary in practice are given in my report on the structure of the nucleus (Smithsonian Contributions, No. 1373, 1892), to which reference will frequently be made. A is a tall glass vessel about one meter high, either cylindrical or rectangular in section, in the latter case with opposed plate glass sides. The liquid, L, whose vapors are to be tested, is placed in the bottom. The wide tube, c, is used for sudden exhaustion, while a vacuum gauge, g, registers the pressure differences. The tubes a and b to the *top* and the *bottom* of A serve for the admission either of filtered air or of nucleated air. They are used together, one for influx and the other for efflux, in connection with the suction of an aspirator.

When the diffusion of the necessarily heavy vapors from L is to be measured, the air in A is first cleansed of vapor by a current of nucleated air from a to b. Thereafter the stopcocks are closed at a stated time. If now at a subsequent time a sudden exhaustion is made in A through c, for a stated pressure difference $\delta p'$, shown at g, the progress of the diffusion may be computed from the height of the fog-bank after an allowance is made for the rise due to the exhaustion.

On the other hand, if the aspirating current is of *filtered* air and moves in the direction from b to a, over the surface of the *volatile* liquid, the receiver, A, should become uniformly saturated to a high degree throughout. If nuclei are added at a stated time below, near the surface of the liquid, the corresponding height of the fog-bank seen on exhaustion at a later time, should indicate the rate at which the nuclei diffuse, if they diffuse more slowly than the residual concentration of vapor. This method for nuclei, which I pursued with entire confidence, leads however to erroneous results, as the present paper will show: for the diffusion of the nuclei is a much more rapid process than the accompanying complications of vapor diffusion.

2. To state the case specifically, let p be the vapor pressure relative to the saturation pressure at the temperature ϑ_0, at a time t after diffusion of vapor commences and at a height x

* Paper contributed to the meeting of the National Academy, April, 1903.

above the surface of the liquid in the receiver, A. Then from well known principles it may be shown that

$$p = 1 - \frac{2}{\sqrt{\pi}} \int_0^{x/2\sqrt{kt}} \epsilon^{-q^2} dq \qquad (1)$$

where k is the coefficient of pressure diffusion.

If the exhaustion at the time t is made adiabatically from air pressure p'_0 to p' corresponding to the temperatures ϑ_0 and ϑ', the relation is approximately $\vartheta'/\vartheta_0 = (p'/p'_0)^{(\gamma-1)/\gamma}$ where a correction for precipitated liquid, etc., is needed.

The vapor pressure corresponding to the reduced temperature ϑ' so obtained after division by the saturation pressure at ϑ_0, is then the value of p in equation (1), which therefore like x and t is known so that k may be computed.

3. In order to have an example for use in the discussion below, I computed the case for water vapor, which though unsuitable from its lightness for experiment, is convenient for comparison with other vapors, almost all of which are heavier than air. The well known expansion of (1) judiciously manipulated is sufficient for the purpose, though I afterwards availed myself of the tables in Dienger's Method of Least Squares in the absence of larger tables.

Table I.—Pressure diffusion of water vapor into air. Initial ($t = 0$) saturation, $p_0 = 0$. $k = ·23$ at 20°.

Time t	Values of p when height of fog-bank $x =$ 1cm	5cm	10cm	20cm	40cm	60cm
1m	·85	·34	·06	..	..	..
5	·93	·68	·40	·10	..	..
10	·94	·77	·56	·24	·02	..
20	·97	·83	·68	·40	·10	·01
40	·98	·88	·77	·56	·24	·08
60	·98	·91	·81	·63	·34	·15
100	·99	·92	·85	·71	·45	·26
	The same for the initial saturation, $p_0 =$ ·33.					
1m	·90	·56	·37	..	..	..
5	·95	·79	·60	·39	..	..
10	·97	·84	·71	·49	·34	..
20	·98	·89	·79	·60	·39	·34
40	·98	·92	·84	·71	·49	·38
60	·99	·94	·87	·75	·55	·43
100	·99	·95	·90	·81	·53	·50

The results for water vapor are given in Table I, where the time, t, is in minutes and the height of the fog-bank, x, is in centimeters.

The table also contains a second series of data, in which the diffusion takes place into a vapor $\frac{1}{8}$ saturated, to which reference will be made below. The results of Table I may be constructed graphically, showing respectively the advance of diffusion at a given height or at a given time. The latter are exhibited in connection with figure 1. From either set of curves the parabolas which show the rise of a given vapor pressure in the lapse of time may be obtained by graphic interpolation.

If the exhaustion chosen is such as to reduce the vapor pressure to $\frac{1}{8}$ the intersection of the vertical line of the figure with the successive curves will show the heights of the fog-banks on condensation. Thus after 20, 40, or 60 minutes the fog-banks having attained heights of roughly 23, 33, and 40 centims., will be in good position for observation.

For any other vapor than water, the times will increase inversely as the coefficients of diffusion. Thus for benzol § 4, the time intervals should be increased about $2\frac{1}{2}$ times; etc.

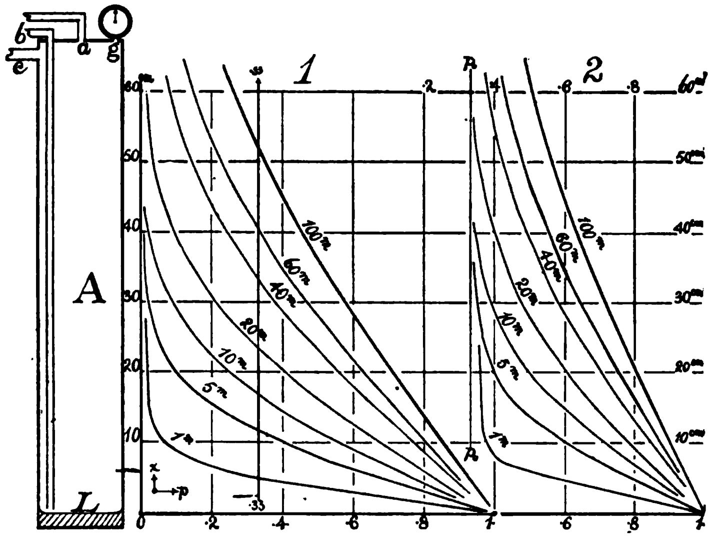
4. The feature of these curves is the extreme slowness of diffusion even for water vapor. At but 20^{cm} above the liquid surface it takes half an hour to reach semi-saturation. The case is accentuated for other liquids where the coefficients are smaller, as for instance for the following liquids at about 20° ;

Vapor,	CS_2	C_6H_6	H_2O	CH_4O	C_2H_6O	C_3H_8O
$k=$	·1	·09	·23	·16	·12	·07

If therefore the fog particles are relatively large and subside rapidly, the air will soon become highly desaturated. In other words, if the air in the receiver A is cleaned of nuclei by condensation, there is no vapor available to replace the liquid lost.

In case of water vapor the fog particles are small and subside slowly while the vapor is lighter than air. Hence the latter is liable to be reheated from the rapid radiation of gases assisted by convection as stated, before much desaturation takes place, unless the vessel is very long and the sides dry. The opposite is the case for the hydrocarbon vapors in spite of their volatility, since the fog particles are larger and fall rapidly and the vapors are heavier than air. After successive precipitation at a given pressure difference, the vapor may be so far desaturated that it nearly ceases to condense even if nuclei are present. It cannot quite cease to respond, for some vapor must return to the air after condensation almost instantaneously; but it is not improbable that a vapor exhausted to a slightly higher pressure difference will fail to condense thereafter at the original pressure difference. Thus there is considerable chance for error in judgment and what is taken for the diffusion of nuclei

added near the surface of the liquid may actually be the diffusion of the liquid itself. This will even be the case if an aspiration current, as in § 1, falls sufficiently short of saturation, supposing always that the velocity of nuclei is relatively large. True, in the experiments which I made the two sets of results for nuclei and for vapors differ in order of values, in distribution among different vapors, in forms of loci, while for carbon disulphide the gradually increasing apertures of the coronas is certain evidence of greater concentration of nuclei. But these and other occurrences may each in their turn be explained away.



5. To facilitate the discrimination in question the diffusion of vapor into partially saturated vapor may be computed as has already been done in Table I, where

$$p = 1 + \frac{2}{\sqrt{\pi}}(p_0 - 1)\int_0^{x/2\sqrt{kt}} \epsilon^{-q^2}\,dq$$

and the initial saturation is $p_0 = \frac{1}{8}$ at $t=0$. The results of the table are constructed in figure 2 and from them the parabolas showing the rise of the levels of successively increasing saturation may be derived.

An inspection of figure 5 shows that if the exhaustion were carried somewhat further than corresponds to the lower limit $p=\frac{1}{8}$, the fog-banks would be capped at a definite height, and that the latter would be enormously influenced by slight

changes of pressure decrement on exhaustion. Experiments bears this out. Even for fixed air pressure differences ($\delta p'$), the condensation must progress with a sweep from the bottom upward, and if the very small particles last formed evaporate fast enough, an upper demarcation of the fog-bank will again show itself which would easily be mistaken as a true case of the diffusion of nuclei. In this way the diffusion of about semi-saturation ($p = \cdot 5$) into benzol vapor initially about $\frac{1}{8}$ saturated would fully account for the apparent diffusion of nuclei into benzol vapor shown in the memoir cited.

6. Special experiments must therefore be made to decide whether when nuclei are added at the bottom of a homogeneous column of nearly saturated vapor, the observed diffusion is that of nuclei through the vapor, or of a greater concentration of vapor through homogeneous nucleation. For this purpose it is sufficient to add the nuclei in successive experiments at the top and at the bottom of the receiver, A, figure 1. The nuclei in such a case must diffuse alternately downward and upward, while the vapor diffuses upward only. These experiments, since made with care, showed that the addition of nuclei above or below the column of vapor is without effect on the observed diffusion. Hence it follows not only that the diffusion of the vapor and not of the nuclei has been observed, but that the nuclei must diffuse much more rapidly than the vapor. Indeed in the time in which the nuclei travel from top to bottom of the tall vessel nearly 1 meter high, the vapor has scarcely risen and the fog-bank seen on exhaustion lies close to the surface of the liquid.

An attempt to measure this rapid diffusion of the nucleus in benzol vapor by the present direct method failed, chiefly because all attempts to rigorously saturate the air in the receiver with the heavy vapor in a reasonable time were seriously hampered by convection. The results merely showed that the velocity of the nucleus in benzol vapor must be quite of the same order as in water vapor, but sharp data could not be obtained.

Brown University, Providence, R. I.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Solid Fluorine and its Combination with Liquid Hydrogen.*—Moissan and Dewar have shown, some time since, that fluorine liquefies at $-187°$, and that, at this low temperature, it does not act upon crystalline silicon, amorphous carbon, boron or mercury, but that it does combine violently with gaseous hydrogen and solid essence of turpentine. These investigators have recently subjected fluorine to the temperature of boiling hydrogen ($-252{\cdot}5°$). As this cooling takes place the fluorine gas liquefies, then forms a yellow solid, and finally the solid becomes white. It was found that the melting-point of solid fluorine is about 2° higher than that of solid oxygen, or about $-233°$.

The interesting fact was observed that solid fluorine when brought in contact with liquid hydrogen at the temperature of the latter, $-252{\cdot}5°$, produces a violent explosion. It appears, therefore, that chemical energy exists at this low temperature, which is only 20° above the absolute zero.

The solidification of fluorine leaves only one known gas, helium, which thus far has not been brought into the solid condition.—*Comptes Rendus*, cxxxvi, 641. H. L. W.

2. *Hydrides of Rubidium and Cæsium.*—Moissan has prepared the hydrides of the rare alkali-metals rubidium and cæsium, and finds that they correspond exactly to potassium hydride. They correspond to the formulas RbH and CsH, and form colorless crystals. Both compounds are decomposed by heating in a vacuum below 300° into hydrogen and metal. They take fire at ordinary temperatures in air, oxygen, chlorine, fluorine and bromine vapor. Heated in nitrogen gas they form mixtures of nitride and amide. They are decomposed rapidly by water at ordinary temperatures, but without incandescence, forming the metallic hydroxides and hydrogen. When acted upon by sulphur dioxide at low temperatures and diminished pressure they form the hydrosulphites $Rb_2S_2O_4$ and $Cs_2S_2O_4$. At a gentle heat carbon dioxide combines with them to form the formates. They react with ammonia gas and form the amides.—*Comptes Rendus*, cxxxvi, 587. H. L. W.

3. *Combustion in Gaseous Mixtures other than Air.*—Very conflicting statements have been made in regard to the amount of carbon dioxide which, when it is mixed with air, will extinguish a flame; for example, Eulenberg asserts that extinction occurs at 3 per cent of CO_2, Taylor at 10 per cent, Graham-Otto at 20 per cent, and Arnould at 25 per cent. Pelet and Jomini have recently made numerous experiments by using candle, alcohol, and illuminating-gas flames in mixtures of nitrogen and oxygen, carbon dioxide and oxygen, and also in mixtures of the three gases. After the flames had been extinguished the resulting mix-

tures were analyzed. It was found that the combustion of a flame can be maintained in the presence of varying quantities of carbon dioxide, up to as much as 75 per cent, so long as there remains a definite proportion of unburned oxygen in the mixture. For the same combustion the minimum proportion of unburned oxygen at which extinction occurs varies within narrow limits. For example, extinction took place in the following mixtures :

CO_2 Per cent	O_2 Per cent.	N_2 Per cent.
with the candle flame :		
3·6	16·0	80·2
10·8	17·0	72·2
27·8	19 5	52·7
50·0	21·2	27·9
78·	22·	
with the alcohol flame :		
6·7	14·3	79·0
20·3	13·0	66·7
with the gas flame :		
10·4	11·0	78·6
13·3	11·3	75·7
34·4	11·2	54·4

The interesting result is reached, therefore, that, contrary to the prevailing view, carbon dioxide has but little greater effect upon flames than the same amount of nitrogen, but it should be mentioned that in the investigation under consideration it was noticed that when combustion is taking place in the presence of a certain proportion of carbon dioxide, the hydrogen of the substance burns alone, forming water, while the flame smokes, and the carbon dioxide increases but little or not at all.—*Bull. Soc. Chem.*, xxix, No. 5. H. L. W.

4. *The Non-conductivity of Metallic Hydrides.* — MOISSAN has found that the hydrides of potassium, sodium, rubidium and cæsium in compact layers 5^{cm} long do not conduct the electric current, and that the fused hydrides of calcium and lithium behave in the same way. From these results the author concludes that hydrogen is not analogous to the metals, but corresponds to the non-metals, in these compounds, and that these hydrides cannot be considered as alloys of hydrogen with the metals.—*Comptes Rendus*, cxxxvi, 591. H. L. W.

5. *Heat Spontaneously Evolved by Radium Salts.*—It has been shown by CURIE and LABORDE that the salts of radium evolve heat continuously. When one junction of a thermo-electric couple was surrounded by radiferous barium chloride containing about one-sixth of pure radium chloride, and the other junction was similarly enclosed in pure barium chloride, a difference in temperature was indicated, which amounted to 1·5°. The amount of heat evolved in a given time was determined quantitatively by comparison with a wire of known resistance,

which was heated by a measured electric current until it produced the same effect as the radiferous material, and this value was determined also by Bunsen's calorimeter. It was thus found that 1 g. of radium gives off a quantity of heat amounting to about 100 small calories per hour. One gram-atom (225 g.) of radium would therefore give every hour, 22,500 cal., a quantity comparable to the heat evolved by the combustion of 1 gram of hydrogen in oxygen. The authors remark that the continuous disengagement of such a quantity of heat cannot be explained by an ordinary chemical change. If it is supposed that the production of heat is due to an internal transformation, this must be profound in its character, and must be due to a modification of the radium atom itself. However, if such a transformation exists, it takes place with extreme slowness, for the properties of radium do not undergo appreciable variations in the course of several years at least. Therefore, if the transformation hypothesis is true, the energy produced by the transformation of the atoms must be extraordinarily large. The hypothesis of a continual modification of the atom, however, is not the only one compatible with the disengagement of heat by radium, for the fact may be explained by supposing that radium utilizes some exterior energy of unknown nature.—*Comptes Rendus*, cxxxvi, 673. H. L. W.

6. *Analytical Chemistry;* by F. P. Treadwell. *Translated from the Second German Edition;* by William T. Hall. Vol. I, *Qualitative Analysis.* 8vo, pp. xi, 466. New York, 1903. John Wiley & Sons.—This is a rather elaborate work on qualitative analysis, possessing many excellent features. The descriptions of the operations are full and clear and the methods appear to be generally well chosen. However, the retention of the test for barium and strontium with calcium sulphate, which has generally been abandoned, and the omission of the very delicate potassium cobaltic nitrite test for potassium, have been noticed. The equations of the reactions are very fully treated, and the treatment of the acids is unusually extensive. A supplement deals with the rarer metals. Analytical tables, to which some teachers object, are used, but it is the author's experience that these give the best results. The translation appears to have been very well done, but a few errors, particularly in the equations, indicate some lack of care in proof-reading. H. L. W.

7. *Beiträge zur Chemischen Physiologie*, herausgegeben von F. Hofmeister. III. Band, 9–12. Braunschweig: Vieweg und Sohn. 1903.—The most notable contribution in the concluding numbers of this volume is the paper by Stoklasa and his coworkers, giving an account of the anærobic metabolism of the higher plants and its relation to alcoholic fermentation. It is demonstrated that the enzyme *zymase* is widely distributed in the vegetable kingdom, and that alcohol and carbon dioxide are metabolism products excreted by the vegetable cells even under conditions where micro-organisms are completely excluded. The

quantitative relation between the alcohol and carbon dioxide formed are the same as exists in the products of alcoholic fermentation with yeast. Several other papers deal with the chemical aspects of problems relating to immunity and the composition of proteid substances. L. B. M.

8. *Ionization produced by Corpuscles of Radium.*—Professor Townshend estimates that the value of this ionization must be at least 13. J. J. DURACK of Trinity College, Cambridge, believes that this number is seventy-six times too large. He finds that the mean free path of the Becquerel ray corpuscles in air at 1^{mm} is about 6^{mm}. This very large value accounts for the very small absorption of the deflectable Becquerel rays.—*Phil. Mag.*, May, 1903, pp. 550–561. J. T.

9. *Condensation of Radio-active effects.* — Professor RUTHERFORD and Mr. SODDY with the aid of liquid air show that the condensed emanations from thorium and radium possess a true vapor pressure and that the emanations have the usual properties of ordinary gaseous matter, as far as condensation and volatilization are concerned. These emanations are also occluded by solids under certain conditions and therefore seem to be gaseous in nature.—*Phil. Mag.*, May, 1903, pp. 561–576. J. T.

10. *Radio-active Change.* —Professor RUTHERFORD and Mr. SODDY, in a discussion upon the amount of energy stored in radio-active substances, hazard the suggestion that atomic energy in general is of a high order of magnitude and that the existence of this energy accounts for the stability of the chemical elements.

The maintenance of solar energy may be due to the available internal energy of the atoms.—*Phil. Mag.*, May, 1903, pp. 576–591. J. T.

11. *Removal of the Potential Difference by Heating in Oil.*—J. BROWN, F.R.S., in earlier papers has suggested that the difference of potential due to contact of metals might arise from the chemical action of films condensed on their surfaces. His recent work confirms this theory. On the first immersion of the metals in cold oil the films acted as if in air though with less deflection, due probably to minute conductivity of the oil, which reduced the potential difference. When heated to above the boiling point of water the films evaporated and left nothing to act electrolytically on the plates. After removal of the oil the moisture of the air found access to the plates and a difference of potential was again observed.—*Phil. Mag.*, May, 1903, pp. 591–594. J. T.

12. *On the Thickness of the Liquids formed by Condensation at the Surface of a Solid.*—Dr. G. J. PARKS refers to the previous knowledge in regard to condensation of liquids and gases on the surfaces of solids. The author was led to consider the quantity of moisture concerned in surface pressure, in the Pouillet effect, and in surface action in general. He concludes that in all cases where condensation takes place at a solid surface, and at a temperature not below the dew point, the thickness of the surface

film varies from 10×10^{-6} to 80×10^{-6cm} according to the substances used and the conditions of temperature and pressure, and for the water film on glass in saturated vapor at 15^c the thickness is about 13×10^{-6cm}. The author quotes Professor B. J. Thomson's results for the mean radius of drops formed by condensation in electrified gas, namely 89×10^{-6cm} for negatively electrified oxygen and 68×10^{-6cm} for positively electrified oxygen.—*Phil. Mag.*, May, 1903, pp. 517–523. J. T.

13. *Speaking Flames.*—In a preliminary notice V. Gabritschewski and A. Batschinski describe a method of obtaining speech from flames. The poles of an induction coil were connected by wires to Bunsen burners or other flames. The primary circuit of the coil included a battery giving about four amperes and a microphone. The distance of the microphone was about 30^m. The flames repeated various sounds and speech. It is essential that a sufficient difference of potential should arise at the flame electrodes.—*Ann. der Physik.*, p. 223. J. T.

14. *Vorlesung über Experimental Physik;* von August Kundt. Edited by Karl Scheel. Pp. xxiv, 852, with a half-tone of Kundt, 534 figures and a colored spectrum plate. (Braunschweig: Friedrich Vieweg u. Sohn.)—This volume, prefaced by a resumé of Kundt's life and labors, is the result of an earnest desire on the part of his former students to have, in accessible form, the lectures of this gifted investigator and teacher. It has been prepared from Kundt's notes of the lectures he delivered in Berlin ('88–'89) which bear traces of his own editing for publication. There are a total of 150 lectures covering the subjects of Mechanics, including Liquids and Gases, Sound, Heat, Electricity and Magnetism, and Optics—which are models of clearness and thoroughness of presentation.

The editor has preserved, so far as type permits, those characteristics of Kundt which gave him his hold upon the student. Every principle is developed in the simplest and most comprehensible manner from a consideration of the phenomena themselves, which he freely reproduced before his classes. This method is adopted in preference to a mathematical development, though the discussions always lead to the fundamental formulæ.

These lectures will undoubtedly prove of great interest and value to all teachers and students of the subject. D. A. K.

II. Geology and Natural History.

1. *New York State Museum:* Frederick J. H. Merrill, Director.—The following bulletins have recently been received:

No. 44 (vol. viii) Lime and Cement Industries of New York; by Heinrich Ries and Edwin C. Eckel. Pp. 639–968. 102 pls. The origin, composition, geologic occurrence and commercial uses of the New York limestones have been studied with great care and described in such a manner as to be of most use to quarry owners and limestone users. The chapters on the Portland Cement Industry, pp. 849–898, were written by Mr. Eckel.

No. 60 (Zoology 9). Fishes of New York; by TARLETON H. BEAN. 756 pp. The number of fishes included in this descriptive catalogue is 375. Of these species 217 are marine, 141 fresh water, and 17 anadromus. The small number of fresh-water species is due to lack of extensive investigations in the water bodies of the interior of the state.

2. *Geological Survey of New Jersey:* H. B. KÜMMEL, State Geologist. Annual Report, 1902. 149 pp. 5 pls.—Under the guidance of Dr. Kummel the New Jersey Survey is continuing its excellent work, chiefly along the lines of economic geology. The present volume contains reports on the Floods of Feb. 28 to March 5, 1902, by C. C. Vermeule; on Artesian Wells, by Lewis Woolman; on Forestry by F. R. Meier; on the Mining Industry, by Dr. Kümmel and by Mr. Weed. Mr. Knapp is at work on the coastal plain deposits.

3. *Geology and Petrography of the Crater Lake National Park;* by J. S. DILLER and H. B. PATTON. (Professional Paper No. 3, U. S. Geol. Surv., Washington, 1902, 4°, 167 pp., 19 pls.)—In the first portion of this work the geology is described by Mr. Diller. He gives a complete and detailed description of this remarkable body of water lying in a great crater in the top of Mt. Mazama, of the mountain itself and of its geological history and shows in various ways that the mountain was once a lofty peak which, collapsing, left a huge caldera in its place. The latter, filled with water, forms the present lake.

In the second part Professor Patton gives the results of a detailed and careful study of the igneous rocks of the mountain. He shows them to consist of the andesites, dacites and basalts of a number of different types, whose characters as shown by the study of thin sections and by chemical analyses are fully presented. The work is illustrated by half-tones of many fine photographs and in addition to its scientific interest will without doubt be of service as an authoritative handbook when this interesting region becomes quite accessible to the traveling public.

L. V. P.

4. *Preliminary Report on a part of the Granites and Gneisses of Georgia;* by THOS. L. WATSON, Ph.D. (Geol. Surv. Georgia, Bull. No. 9, 8°, 367 pp., 1902.)—This report is limited to a study of the granitic rocks in those counties in which there is a considerable technical production. In the first chapter the general characters of granite are treated; in the second, the properties of rocks in respect to technical purposes are discussed. The author then in the third chapter, after describing the general geology of the area, takes up the occurrences of granite with especial reference to the individual quarries, and in the succeeding one discusses the general chemical and petrographic characteristics of the Georgia granites. The volume concludes with a treatment of the subject of rock weathering with especial reference to the areas and rocks described. The volume shows a large amount of careful work, both in the field and in the laboratory, the results of 70

analyses of fresh and altered rocks being given, and is a useful addition to the general literature of scientific petrography as well as a fund of information for local technical purposes. It is well printed and illustrated by a large number of excellent half tone cuts and is a production creditable alike to the author and to the state survey. L. V. P.

5. *L'Age Des Formations Sédimentaires de Patagonie;* by FLORENTINO AMEGHINO. "Annals Soc. Cientif. Argentina," L and LIV, pp. 3–231, Buenos Aires, 1903.—It is not my intention to review this rather lengthy paper, the exact nature of the contents of which is scarcely intimated by the title. Nor does Dr. Ameghino's declaration on page 5 that "C'est une discussion exclusivement scientifique que ja vais tacher d'examiner en conscience et sans aucun préjugé," seem to have been kept constantly in mind throughout the succeeding 225 pages. The entire paper is devoted almost exclusively to a critical review of the literature of various authors upon the geology and paleontology of Patagonia, and the amount of space allotted to the three or four brief preliminary papers published by myself (this Journal, iv, 246–248; 327–354; ix, 85–108) is such that I ought certainly to feel flattered by the attention bestowed upon my work in Patagonia by Dr. Ameghino, the learned director of the National Museum at Buenos Aires. However, for the benefit of those who may not have access to Dr. Ameghino's paper, it is only proper for me to state in this connection that Dr. Ameghino's estimation of the value of my work in Patagonia is in inverse proportion to the space he has devoted to its criticism.

As to those matters relating purely to the geology and paleontology of Patagonia, wherein we differ, I shall have nothing to say at present. Having already stated my opinions and given in some detail my reasons therefor in my preliminary papers, I am content to await the publication of my final report on the geology of that region for a further elucidation of my views. In the meantime I must refer those interested in these questions to such of my publications as have already appeared, where they will find all important localities mentioned by me designated and described with such detail that they may be revisited and re-examined. I am so far from considering myself as infallible that I have always taken the precaution to preserve and publish detailed descriptions of all important localities in such manner that they may be easily revisited and identified by subsequent investigators. I shall always respect the opinion of any really competent observer, who revisits and re-examines any of the localities visited by me in Patagonia, regardless of whether his interpretation of the facts there displayed do or do not agree with those of myself. I do, however, believe that geology as a science is somewhat different from astronomy, and that it can only properly be studied at close range and not from a distance. Even so capable a man as Dr. Ameghino should, I believe, find

some difficulty in carefully determining the exact sequence of strata in Patagonia from the window of his study, situated in La Plata or Buenos Aires. Nor can I agree with Dr. Ameghino that he has satisfactorily answered my appeal to him for the publication of more exact localities by the reply given on page 8, that "Les recherches de C. Ameghino ont été faites à mes frais, pour mon instruction personelle et au profit de la science. Je n'avais pas l'obligation de faire des rapports détaillés. J'ai toujours tenu à donner des résumés des recherches géologiques de mon frère à fin que l'on put se rendre compte de la succession des faunes que je décrivais; mais je n'ai pas eu l'intention, et je n'en avais pas non plus l'obligation, de rédiger un guide avec les instructions nécessaires pour la récolto de fossiles."

I think those who are acquainted with me or my work will grant that I am fairly competent, as a collector of vertebrate and other fossils, and not one of the many who have applied to me in years past for localities will say that I did not at all times give them free and full information, nor in doing so have I ever considered that I was acting as a *guide*. I had no idea, when, on my first visit to Dr. Ameghino, he refrained from indicating to me on a map spread before him the location and distribution of his Pyrotherium beds, that he entertained the really *childish* ideas which seem to have inspired the lines quoted above, or I should never have urged his brother Charles when we were together at Santa Cruz in the winter of 1898, to join me in an expedition the following season to re-examine together the different Tertiary and Cretaceous horizons of Patagonia. Dr. Ameghino's remarks, just quoted, fully explain to me the reason why his brother, after fully agreeing with me as to the desirability of such a joint expedition and setting a time and place for our meeting the following spring to undertake the same, shortly after his return to La Plata wrote me that it would be impossible for him to keep the engagement, and that I must not wait for him to join me.

Since on page 18 of his paper Dr. Ameghino attacks my integrity and seems to infer that I have not acted in good faith in quoting the remarks of his brother relating to the manner in which he (Charles) had really found the mammalian and dinosaurian faunas of the *Pyrotherium* and *Guaranitic beds*, I hope I may be pardoned for a few brief remarks in defense of my position. After quoting me at some length Dr. Ameghino continues as follows: "Je repousse cette forme de discussion que, et j'en demande pardon à M. Hatcher, ne me parait pas trop correcte; il a supris la bonne foi de mon frère en lui raccontant que j'ai dit, ce qu'en vérité je n'ai jamais dit. C'est tout clair: il a demandé à Charles s'il avait trouvé des débris de mammifères associés à ceux de Dinosauriens, et il lui repondit, non. Si en place de cela, il lui aurait demandé s'il avait trouvé des débris de mammifères dans la même formation qui contient des os de Dinosauriens, certainement il lui aurait répondu, oui. Pourrait-il M. Hatcher m'indiquer, où, dans quel ouvrage, et à quelle page j'ai dit que C.

Ameghino a trouvé des os de mammifères associés à des os de Dinosauriens? Nulle part! La traduction de l'article dont parle M. Hatcher est parfaitement correcte, mais la traduction que lui en a donné à mon frère, qui ne lit pas l'anglais, est complètement inexacte. Dans l'article dont lui fait mention, tout ce qu'à ce sujet je dis, c'est: "That this formation is secondary, is clearly indicated by the Dinosaurs; on the other hand, as its upper beds pass insensibly into another formation, which contains numerous remains of mammals, it cannot be doubted that the sandstones with Dinosaurs belong to the upper Cretaceous."

"In Patagonia the beds with remains of Dinosaurs pass insensibly into other beds with numerous remains of mammals, particularly of ungulates, which circumstance proves that the red sandstones ought to be referred to the Upper Cretaceous."

It will be noticed that Dr. Ameghino does not accuse me of misquoting his brother's remarks to me. He also admits that the translation in the Geological Magazine of the article referred to is perfectly correct, but claims that my translation of it to his brother was completely incorrect. He denies ever having stated that C. Ameghino had found the bones of mammals associated with the bones of Dinosaurs and calls upon me to indicate in what work and on what page he has said this, closing with the exclamation, Nulle part! (No where). Now if Dr. Ameghino will but turn to page 10 of his "*Notes on the Geology and Paleontology of Argentina*" (the same article from which he quotes) as translated and published in the Geological Magazine for January 1897, which translation, he tells us, is perfectly correct, commencing with the first paragraph from the bottom he will find the following sentences: "I rely on the fact that these beds with remains of Pyrotherium everywhere accompany the red sandstones with remains of Dinosaurs, so that it has not hitherto been possible to separate them in an absolute manner. These sandstones in certain places exhibit nothing but bones of Dinosaurs; in others they show only remains of mammals and smaller reptiles of types not yet determined; *while at other points all these remains are shown mixed together* (italics mine), at least to all appearance, always accompanied by a great quantity of silicified wood." From this I think my readers will agree with me that the two short paragraphs quoted by Dr. Ameghino were not quite all that he said on this subject in that paper, and that I was fully justified in asking Charles Ameghino if he *had found* the remains of mammals associated with those of Dinosaurs, more especially since Dr. Ameghino has himself never seen any portion of Patagonia, and all that he has written on that country is based upon the observations of others and chiefly on those of his brother.

The same methods as those just shown are pursued throughout the entire paper, which abounds in quotations so adroitly made as to destroy the original meanings of the context, by substituting others never intended or implied by the various

authors criticised. Nor is this to be wondered at, for if Dr. Ameghino is so unfamiliar with his own published statements as to make the errors cited above, he can scarcely be expected to familiarize himself with the work of others. He affirms that I have never seen the *Pyrotherium beds*, and reproaches me, therefore, for having said anything about them, notwithstanding the fact that his brother Charles distinctly stated to me that certain deposits on the upper Rio Shehuen, with which I am acquainted, pertain to these beds. Not having myself found any characteristic fossils in these deposits, I relied entirely upon the determinations of Charles Ameghino as to their identity, and I still have no good reason for doubting the correctness of his determinations, but every reason for doubting the age ascribed to them by Dr. Florentino Ameghino.

Again, in speaking of the lakes of Patagonia, Dr. Ameghino reproaches me, and not without some reason, for venturing to say anything concerning Lakes Colhue and Musters, neither of which I have ever seen. This fact, one would infer, is in Dr. Ameghino's opinion sufficient reason why I should have remained silent. Indeed I am half inclined to agree with Dr. Ameghino in this matter, and I only wonder why it has never occurred to him to apply the same rule of stricture to his own publications, for I fully realize the confusion that might thereby have been avoided concerning the geology of Patagonia, a country he has never visited. J. B. HATCHER.

6. *Catalogue of Meteorites in the Vienna Museum.* — Prof. F. BERWERTH has published (Annalen des k. k. naturhistorischen Hofmuseums, Wien, Bd. xviii) a catalogue, with two appendices, of the meteorites in the Vienna Museum at the close of October, 1902. The catalogue shows that this collection still retains its rank as the largest in the world, the total number of falls represented being 560, and the total weight of cosmic matter exhibited 3,313 kilograms, of which 2,553 kilograms are meteoric irons, 122 kilograms ironstones, and 637 kilograms stones.

In the first part of the catalogue the falls represented in the Vienna collection are grouped chronologically under the separate divisions of irons, iron-stones and stones. Relegation of Santa Catarina to the group of pseudo-meteorites is a noteworthy change here and one with which most students of meteorites will agree. On the other hand, the grouping of the meteorites of Prairie Dog Creek, Jerome, Kansada and Ness County under the one head of Prairie Dog Creek, is not likely to meet with unqualified approval.

The first appendix gives an alphabetically arranged list of all known meteorites, with their classification, date of fall or find, and latitude and longitude of the locality from which each was obtained. It is to be regretted that the latter feature seems somewhat lacking in accuracy, errors of several degrees being observable in more than one case. In choosing names for the falls, Prof. Berwerth has followed in general the plan of giving

the meteorite the name under which it was originally described, rather than that of the nearest locality. Priority is thus deemed of more importance than geographical position, and a somewhat elaborate defense of this course is given in the preface. Its advisability may, however, be questioned, especially as it causes many American falls to be named from counties rather than from towns.

In the second appendix a list of known meteorites by countries is given, a work which, like the catalogue as a whole, affords information of great usefulness to students of meteorites.

O. C. F.

7. *The Eruption of Colima.* (Communicated by F. L. SPERRY.)—"The volcano of Colima in Mexico has been recently in eruption and the following data in regard to it may be of value to students of volcanic phenomena. They were obtained during a recent visit to the city of Zapotlan, Jalisco, Mexico. The volcano is about 100 miles from the west coast and about 25 miles from Zapotlan. Its height is about 12,500 feet and it is a well known landmark. The history of the volcano according to residents of the city is as follows: There was a great eruption accompanied by earthquakes on Oct. 22d, 1742. The next was on March 25th, 1806, with heavy earthquakes which destroyed a church, killing 2,000 of the inhabitants who had sought refuge there. In 1856 there were several eruptions and earthquakes which destroyed houses in Zapotlan, Tuxpan and other places within a radius of 30 miles. The volcano was smoking last July, sending up pillars of steam high in the air, at irregular intervals. At 12.30 P. M. Feb. 18th, 1903, the inhabitants of Zapotlan were startled by a mighty roaring accompanied by slight shocks and the fall of ashes. This was repeated Feb. 20th at 12.30 P. M. At 4 P. M. Feb. 24th there came a fearful eruption with showers of ashes, which shrouded the city in darkness for three hours. These eruptions continued every three or four days until March 9th, when the greatest spectacle of all took place and the material of the eruption was thrown into the city. The fine ash and gases formed a very solid column reaching high in the atmosphere, which remained intact for more than an hour.

On March 10th this spectacle was repeated, then the volcano remained dormant until March 23d at 1 P. M., when there was an eruption which continued for half an hour accompanied by wonderful spectacular effects. Since then the volcano has remained quiet."

(A specimen of the volcanic ash of the eruption of March 9th, collected in Zapotlan and sent to the editors by Mr. Sperry, shows a light gray andesitic material averaging about 1^{mm} in diameter. Examination with the microscope reveals a mass of minute lapilli-like particles angular to subangular, in part vesicular, in part consisting of solid particles of feldspars. The vesicular portion is sometimes of glass but mostly of lithoidal lava. It is too fine to be called lapilli and is rather coarse for "ash." The

fact that material of this nature could be driven the distance from the volcano to the city testifies to the violence of the eruption.) L. V. P.

8. *Report on the Eruptions of the Soufrière in St. Vincent in 1902, and on a Visit to Montagne Pelée, in Martinique*, Part I; by TEMPEST ANDERSON and JOHN S. FLEET. Phil. Trans. Royal Soc., Series A, vol. cc, pp. 353–553, pls. 21–39.—The first part of the report by Doctors Anderson and Fleet contains the following chapters: Physical Features and Geology; the Eruption of May 7th; the Eruption of May 18th; Rains; Geological Effects of the Eruptions; Previous Eruptions of the Soufrière; the Soufrière and Montagne Pelée; Comparative study of the Peléan type of Eruption; General Sequence of volcanic phenomena in the Antilles and Central America in the early part of 1902. The account is full of interest and the illustrations are of very high order.

9. *Megablattina Sellards* (*non Brongniart*): *A Correction.* (Communicated by E. H. SELLARDS.)—The name *Megablattina* proposed for a new genus of cockroaches from the Coal Measures in the April number of the current volume of this Journal, p. 312, I now find to be preoccupied, having been applied by Brongniart in 1885 to an insect from the Saarbrucken Basin, Germany, previously described by Goldenberg under the hemipterous genus *Fulgorina*. I now suggest for the American genus the name *Archoblattina*.

Yale Museum, May 5, 1903.

10. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes.* Edited by J. STANLEY GARDINER. Vol. I, Part IV, pp. 347–471, 43 figs., 4 pls.—This completes the first volume (this Journal, xiii, 321; xiv, 74; xv, 240). Appendices B and C conclude Mr. Gardiner's valuable reports on the Coral Reefs. Others on the Cephochorda and Lithothamnia are of especial interest. C. F. Cooper gives two species of Amphioxus,—the West Indian *Asymmetrum lucayanum* (Andrews), which is very common, and the new and rare form, *Heteropleuron Maldivense*; also some undetermined larvæ. R. C. Punnett gives interesting results of his study of the "Meristic variation" of the group, showing that increase in number of gonads is associated with decrease in number of segments, and suggests that *genetic selection* may prove a factor of importance in modifying these features. M. Foslie reports nine forms of the little known calcareous algæ (Lithothamnia), none having ever before been recorded from the area between the Red Sea and the East Indies. H. Gadow and J. S. Gardiner give a list of twenty-six birds. F. E. Beddard records three species of earthworms, one of which is new. L. A. Borradaile continues his study of the marine crustaceans, reporting on the Brachyura, proposing one new genus *Selwynia*, type *Selwynia lævis* new, and the Cirrepedia. W. F. Lanchester reports on the Stomatopoda. K. J. B.

11. *Catalogue of the Collection of Palæarctic Butterflies formed by the late John Henry Leech;* by RICHARD SOUTH. British Museum, 229 pp., 2 colored pls.—The collection made by Mr. Leech comprises 18,000 specimens representing 1100 species.

12. *The Determination of the Parallax of the Ten First Magnitude Stars in the Northern Hemisphere;* by WM. L. ELKIN. Trans. Astronomical Observatory of Yale University, vol. i, pt. 6, pp. 259–330.—This publication gives the details of the results of one part of a plan entered into some years ago by the author and Sir David Gill, Her Majesty's astronomer at the Cape of Good Hope, by which the latter was to make a similar determination for the brightest southern stars.

The work was begun in 1885 and the original plan of securing some fifty heliometer measurements of each star was completed in 1891. A discussion of the results showed that the hoped-for degree of accuracy had not in every case been attained, and accordingly further series were made extending through the year 1894.

The author in his characteristic, painstaking manner, has discussed every possible source of error and has deduced the best results possible from his accumulated material. His final results are as follows:—

α Tauri	$\pi = + 0''\cdot109 \pm 0''\cdot014$
α Aurigæ	$= + 0''\cdot079 \pm 0''\cdot021$
α Orionis	$= + 0''\cdot024 \pm 0''\cdot024$
α Canis minoris	$= + 0''\cdot334 \pm 0''\cdot015$
β Geminorum	$= + 0''\cdot056 \pm 0''\cdot023$
α Leonis	$= + 0''\cdot024 \pm 0''\cdot020$
α Bootis	$= + 0''\cdot026 \pm 0''\cdot017$
α Lyusis	$= + 0''\cdot082 \pm 0''\cdot016$
α Aquilæ	$= + 0''\cdot232 \pm 0\cdot''019$
α Cygni	$= - 0''\cdot012 \pm 0''\cdot023$

In the probable errors here given is included an estimated systematic error, which has increased the magnitude of the probable errors about fifty per cent.

The small result found for Arcturus (*α* Bootis) was somewhat surprising in view of the well known large proper motion possessed by this star, which would naturally lead us to think it one of the nearest. It was at first thought the anomalous result might possibly be due to the star's color, but investigations upon other red stars made at the Yale Observatory and by several other heliometer observers, as well as a special analysis by the author of his own measures of this star, indicate that this can hardly be the explanation. It is understood that a further series of observations of this star, to be carried out on somewhat different lines, is now in progress at the Yale Observatory. C.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.* — The annual meeting of the National Academy of Sciences was held in Washington, April 21, 22 and 23. President Ira Remsen was elected vice president and Professor Simon Newcomb foreign secretary. The following gentlemen were elected members: T. C. Chamberlin of Chicago, William James of Cambridge, E. L. Mark of Cambridge, Arthur G. Webster of Worcester, Horace L. Wells of New Haven.

The following papers were presented:

Henry F. Osborn: An estimate of the weight of the skeleton in the Sauropoda, or in the Sauropodous Dinosaurs. New characters of the skulls of Carnivorous and Herbivorous Dinosaurs. Models illustrating the evolution of the Amblypoda, also of the Dinosaur *Diplodocus*, together with a theory as to the habits of the Sauropoda.

George F. Barker: Radio-activity of thorium minerals.

J. M. Crafts: The law of catalysis in concentrated solutions. The standardization of thermometric measurements.

George E. Hale: The Rumford spectroheliograph of the Yerkes Observatory.

Lewis Boss: The determination of standard right-ascensions free from the personal equation for star-magnitude.

R. A. Harris: On the semi-diurnal tide of the northern part of the Indian Ocean.

Arthur L. Day: The melting point of a simple glass.

Carl Barus: The diffusion of vapor into nucleated air.

H. P. Bowditch: Biographical Memoir of Theodore Lyman.

Alexander Agassiz: The nomenclature of the topography of the bottom of the oceans.

S. Weir Mitchell: On the discovery of an antidote for rattlesnake poison.

Alexander Graham Bell: On the tetrahedral principle in kite structure.

Theodore Gill: Biographical Memoir of J. E. Holbrook.

George F. Barker: Biographical Memoir of Matthew Carey Lea.

S. F. Emmons: Biographical Memoir of Clarence King.

Jeffries Wyman: Biographical Memoir of A. A. Gould.

Charles S. Hastings: Biographical Memoir of James E. Keeler.

2. *International Catalogue of Scientific Literature.* — First Annual Issue: A. Mathematics, May, 1902. Pp. xiv, 201. B. Mechanics, July, 1902. Pp. xiv, 128. C. Physics, Part I, February, 1902. Pp. xiv, 239. E. Astronomy, May, 1902. Pp. xiv, 303. F. Meteorology, including Terrestrial Magnetism, May, 1902. Pp. xiv, 184. Q. Physiology, including Experimental Psychology, Pharmacology and Experimental Pathology, Part I, February, 1902, xiv, 404. R. Bacteriology, May, 1902, xiv, 314.—Seven volumes of the International Catalogue of Scientific Literature have recently appeared. They are in every way worthy of the Royal Society, under whose auspices they are published, and are of very great value to the scientific worker. The details of the plan of publication, cost, etc., are given in the preface to each volume. (See, also, this Journal, xiv, 317, October, 1902.)

3. *Carnegie Institution of Washington.* Year Book No. 1, 1902, pp. i–xlvi, 1–305.—The founding of the Carnegie Institution for the promotion of study and research by a gift of ten millions of dollars, given by Andrew Carnegie in January, 1902, is known to all students of science. This first year book contains copies of the official documents by which the Institution was established and minutes of the meetings, held by the trustees during the first year of incorporation. The proceedings of the Executive Committee are also given in abstract, of which the more important items are the announcement of the composition of the several Advisory Committees, and definite statements of the purposes, principles, organization and policy of the Institution.

The plans and methods thus far agreed upon may be indicated by quotation of a few extracts from the Summary at the close of this portion of the book, viz: "The methods of administration of the Carnegie Institution thus far developed are general rather than specific; . . . Attention has been concentrated upon a selection of those objects which, at this time and in our country, seem to require immediate assistance; . . . Efforts have been and will be made to secure coöperation with other agencies established for the advancement of knowledge, while care will be exercised to refrain from interference or rivalry with them; . . . Specific grants have been and will be made, for definite purposes, to individual investigators, young and old, of marked ability, and for assistance, books, instruments, apparatus, and materials."

Provision is made to enable highly qualified persons to profit by the advantages for research afforded by the various scientific bureaus of the United States Government at Washington,—for the appointment of research assistants annually to make special investigations—for publishing the results of research. Preliminary inquiries will be made regarding proposed large undertakings to determine their prospective value and cost. Special advisers have been and will be invited from time to time to report as experts upon questions submitted to them. At the meeting of the Board of Trustees, November 25, 1902, \$50,000 was appropriated for administration expenses, \$200,000 for grants for research during the fiscal year 1902–3, \$40,000 for the publication fund, and \$100,000 was set apart as a reserve fund.

Following the official report are two appendices, consisting of A, Report of Advisory Committees, and B, Proposed Explorations and Investigations on a large scale. Eighteen advisory committees were appointed, and the fields of research thus emphasized indicate the scope of science which is covered at the present time by the operation of the Carnegie Institution. The subjects upon which these advisory committees reported are as follows, viz: economics, botany, physics, geology, geophysics, geography, meteorology, chemistry, astronomy, paleontology, zoology, physiology, anthropology, bibliography, engineering, psychology, history and mathematics. In addition to these the special proposals in Appendix B are for biological surveys of the

Palearctic region, of South and Central America, of the Antarctic, and of the ichthology of the Pacific Ocean; for the establishment of biological experiment stations for the study of problems of evolution; and for making investigations of subterranean temperatures and gradients.

The specific recommendations made by the several advisory committees are significant as indicating the particular trend of scientific investigation at the present time. Among these some of the more important are the following, viz: In botany, relation of vegetation to environment, research in the West Indies; in geophysics, distribution of terrestrial density, upheaval and subsidence in organic dynamics, the operative causes of vulcanism, diathermacy of the atmosphere, tidal deformation, deformation of rocks under stress, mass distribution and variation in density of the earth, gases held in magmas, physical chemistry of natural solutions and precipitates, relation of pressure to melting point; in geography and meteorology, investigation of the upper atmosphere; in astronomy, solar observatories and the study of quantity and nature of solar radiation, establishment of observatories in the southern hemisphere, celestial photometry and photography, astrophysical research as to the physical and chemical constitution of heavenly bodies, and the tracing out and explanation of the successive stages in their evolution from nebulæ, determination of the question, does the force of gravitation vary exactly as the inverse square; in paleontology, the establishment of standard bench-marks for the geological time scale; in anthropology, establishment of laboratories for the study of development of physical types of men, the archæology of native peoples of America, the systematic study of the vanishing tribes of American aborigines; in psychology, investigation in comparative or zoological psychology, and in anthropological and social psychology; in history, an institute for historical research in Washington, and the conducting of research of American history among European archives; in biology, experimental forms and laboratories for studying problems of evolution, especially as to the effects and conditions of environment upon the development and evolution of organisms, and broad explorations in various parts of the earth to determine the laws of distribution and migration and origin of the present faunas and floras of the earth. The administration of the Carnegie Institution is placed in the hands of a Board of Trustees composed of twenty-seven members, who chose John S. Billings, Daniel C. Gilman, Abram S. Hewitt, S. Weir Mitchell, Elihu Root, Charles D. Walcott and Carroll D. Wright to be its first Executive Committee, and Daniel C. Gilman, President, and Charles D. Walcott, Secretary.

H. S. W.

Obituary.

Josiah Willard Gibbs, Professor of Mathematical Physics in Yale University, died April 28, aged 64. (A biographical notice will appear later.)

INDEX TO VOLUME XV.*

* This Index contains the general heads, BOTANY, CHEMISTRY (incl. chem. physics), GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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